NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE IMPACT OF TURN AROUND TIME IN BRAZILIAN NAVY INVENTORIES

by

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December 2000

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2000	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE: The Impact of Turn Around Time in Brazilian Navy Inventories			**5. FUNDING NUMBERS**
6. AUTHOR(S) Mauricio Casagrande			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**. PERFORMING ORGANIZATION EPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			**12b. DISTRIBUTION CODE**

13. ABSTRACT *(maximum 200 words)*

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14. SUBJECT TERMS Inventory Management, Operational Availability, Simulation Modeling, Transportation Costs, Aviation Depot-Level Maintenance			**15. NUMBER OF PAGES** 86
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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THE IMPACT OF TURN AROUND TIME IN BRAZILIAN NAVY INVENTORIES

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
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This thesis analyzes how the operation of helicopters produced and supported by manufacturers in various countries affect Brazilian Navy repairable inventories levels and costs. The research is based on a scenario where the Brazilian Navy operates 68 helicopters, manufactured by contractors in USA, France, England and Italy, and the Brazilian Navy relies on these manufacturers for depot-level maintenance. We develop a simulation model representing the repair process of a group of critical helicopter components and measure the turn-around time (TAT). We also develop a readiness based model to find the optimal inventory level of the selected group of helicopter components to achieve a desired operational availability under these TATs. The results were applied to a spreadsheet model to find the differences in spare levels and associated costs necessary to operate the helicopter fleet. Our research concludes that the helicopter's source has a substantial impact on repairable inventories levels and costs. Furthermore, this impact is large enough to influence decisions in the Brazilian Navy acquisition process of equipment and weapons systems.

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LIST OF SYMBOLS

A_o	Operational Availability
m	Mean Annual Demand
T	Average Repair Time
μ	Average Pipeline
Δ	Marginal Decrease in Expected Backorders

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I. INTRODUCTION

A. BACKGROUND

Because of the rapid advancement of weapons systems and the evolution of electronic warfare, only a few nations are able to support their own military material. The Brazilian Navy must rely on contractors in the United States of America (USA) and in various European nations in order to cover its main material needs and to repair and maintain complex equipment and weapons systems.

The Brazilian Navy Helicopter fleet is composed of 68 helicopters produced in four different countries: USA, France, England and Italy. The Brazilian Navy repairable-item inventory system is a set of organizations and processes that are responsible for the repair and maintenance of these complex components. This system faces long and very different Turn-Around-Times (TAT) when dealing with maintenance providers in each country because of dependency on foreign support. The time needed to repair the same component can double from one provider to another. [Ref. 1]

One of the consequences of this different TAT is that in order to achieve the same Operational Availability (A_o), the Brazilian Navy has to maintain different levels of components to support each type of helicopter it operates. Considering that these repairable components can represent the largest investment in supply support, even small variations in their levels can lead to significant differences in inventory costs. [Ref. 2]

Besides operational characteristics, costs are one of the most important factors that influence the Brazilian Navy source selection during the acquisition of a new

equipment or weapon system. However, during the acquisition process only the costs associated with the initial buy of spares and repair parts are considered. There is no assessment of the costs resulting from the variation in inventory levels caused by the different TATs faced by the Brazilian Navy repairable-item inventory system.

B. PURPOSE

The purpose of this thesis is to identify the impact of TAT on inventory levels and costs when dealing with different sources of supply for main systems.

A simulation model is provided to Brazilian Navy planners to enable them to measure the repairable-item inventory system TAT. An optimization model is also provided to support inventory management and acquisition decisions related to new equipment and weapon systems. The scope of the models is broad, and it is not intended to be a solution for a single case. Instead, we intend to provide the logistics decision-makers with a decision support tool for analyzing the repairable-item inventory system and its impact on A_o and inventory levels.

C. METHODOLOGY

Extensive archival research was done with books, research papers and Internet articles. Telephone interviews were also conducted with personnel from the Brazilian Navy, and relevant data was collected through e-mails. Key personnel involved in those interviews were the Aviation Maintenance Team Leader [Ref. 3], engineers and some logisticians [Ref. 4].

With all information in hand, a simulation software package (Arena) was used to develop a model representing the repair process of a selected group of components. This particular model is an effective tool for long-term decision making on how to improve the

Brazilian Navy repairable-item inventory system. A spreadsheet model was also developed to find the optimal inventory levels necessary to achieve the desired A_o given the TAT faced by each of the different helicopter sources. Ultimately, the results of each source was compared to show the impact of these various TATs on the required inventory levels and the cost.

D. ORGANIZATION OF STUDY

Chapter II provides a review of Brazilian Navy acquisition process. It describes the Integrated Logistic Support (ILS) and supply support costs. Chapter III discusses the Brazilian Navy repairable-item inventory system. Chapter IV presents all the information about the development of our simulation model. Simulation assumptions and model descriptions are included. Chapter V delineates the optimization model used to determine the spare levels required to achieve a desired A_o under each of the maintenance providers. Part of this chapter is dedicated to presenting a brief discussion of Readiness Based Sparing, which is used in the optimization model. Additionally, the impact of the different TATs on DLR Inventory costs are evaluated in this Chapter. The final chapter, Chapter VI, presents conclusions and recommendations.

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II. THE BRAZILIAN NAVY ACQUISITION SYSTEM

A. THE BRAZILIAN NAVY ACQUISITION PROCESS

The Brazilian Navy acquisition process begins with defining requirements, goes through analyzing alternatives, obtaining/acquiring a new system, deployment and ends with the evaluation of the new system. The whole process is divided in five phases. Each phase has specific objectives that must be accomplished before the next phase can begin. [Ref. 5]. Figure 2.1 illustrates the acquisition phases.

The requirement generation is the continuous process of assessing the capabilities of the current force structure to meet the projected threats. The Brazilian Navy High Command conducts this process and determines the acquisition needs of the Navy. Although closely related, the Brazilian Navy considers the requirements determination a process independent of the acquisition process, which initiates only when the budgeting process indicates that the necessary resources to attend the appointed needs will be available.

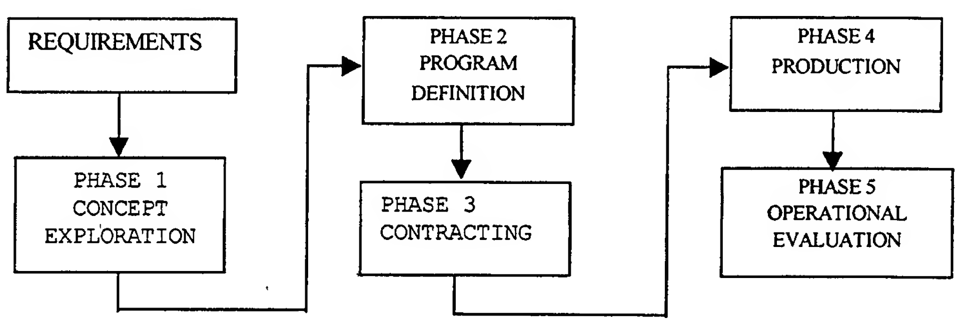

Figure 2.1. The Brazilian Navy Acquisition Process.

The first phase in the acquisition process is the Concept Exploration phase in which a workgroup composed of members from the Chief of Naval Operations Office, Material Command, and Personnel Commands develops concepts and studies for meeting the threat visualized during the requirement generation. In this phase the technical, logistics, military and economic bases for the acquisition program are established. The main objectives of this phase are:

- Explore the various material alternatives.
- Develop the most promising system concept.
- Develop proposed acquisition strategy, initial cost, schedule and performance objectives for the system.

At the end of this phase, the workgroup produces a General Report to the High Command and Navy's Secretary with an analysis of the operative requirements, the systems configuration and the estimated costs obtaining and maintaining the new equipment.

Upon the approval of the General Report of the first phase by the Navy's Secretary the acquisition process proceeds to the Program Definition Phase. In this phase, the Material Command designates a Program Manager to coordinate all the activities related to the acquisition of the new system. In this phase, extensive analysis seeks to validate the major program characteristics such as technical performance, logistics, affordability and development schedules. In addition, manpower, logistics, repair and maintenance parameters critical to system readiness and support costs are identified, and a "Request for Information" is sent to all possible suppliers.

At the end of the phase, the Program Manager produces a new General Report containing an analysis of all the studies made, information obtained and an update of estimated costs to obtain and maintain the new equipment.

With the Navy's Secretary approval of the second phase report, the Program Manager initiates the Contracting Phase, which begins with the requests for proposal preparation and preliminary Navy specification of the contract. The Program Manager proceeds by notifying the potential system suppliers. Once the proposals are received, the source selection process evaluates the proposals and negotiates the awarding of the contracts. In this phase, all the associated logistics and operational support for the selected system begins to be developed.

The fourth phase in the acquisition process is the Production Phase. In this stage the Program Manager administers and monitors the contract for compliance to ensure the conformity of the products delivered against contract specifications. All the associated logistics and operational support for the new system is completed, tested and evaluated.

The fifth and last phase is the Operational Evaluation. This phase begins when the operational command receives the system and tests it under the optimal operational conditions to evaluate its performance. The results are part of the final report made by the Program Manager. This report is used in the evaluation of the acquisition process and as feedback for future acquisitions.

B. LOGISTICS SUPPORT

The introduction of new systems and equipment in any organization requires that a combination of resources in various forms, materials, personnel, maintenance facilities, etc., are readily available to support the operation of this system through its planned life

cycle. These sustaining maintenance and support functions are included within the concept of logistics. [Ref. 6]

The Brazilian Navy assures that all the logistics aspects related to a new weapon system are considered in the acquisition process by adopting the same concept of Integrated Logistics Support (ILS) used in the United States Department of Defense. A formal and precise definition of ILS is presented in DoD 5000.2, part 7A, "Integrated Logistics Support", as [Ref. 7]

> A disciplined, unified and iterative approach to the management and technical activities necessary to:
>
> - Develop support requirements that are related consistently to readiness objectives, to design, and to each other,
> - Integrate support considerations effectively into the system and equipment design,
> - Identify the most cost-effective approach to supporting the system when it is fielded, and
> - Ensure that the required support structure elements are developed and acquired.
>
> The Program Manager is responsible for the ILS planning and preparation, and must address the following elements of logistics support during the acquisition process:
>
> - Manpower and personnel,
> - Supply support,
> - Technical data,
> - Training and training support,
> - Maintenance planning,
> - Computer resources support,
> - Design interface,
> - Facilities,
> - Support equipment, and
> - Packing, handling, storage and transportation.

The Program Manager during ILS planning estimates the costs of each of these logistics elements which together with the system acquisition cost results in the life-Cycle cost of the system. The life-cycle cost is one of the most important factors influencing the source selection process in the contracting phase of the acquisition process. [Ref. 8]

C. SUPPLY SUPPORT

> For many systems, the costs associated with design and development, construction, the initial procurement and installation of capital equipment, production, etc., are relatively well known. However, the costs associated with utilization and the maintenance and support of the system throughout its planned life cycle are somewhat hidden. At the same time, it has been indicated that a large percentage of the total life cycle cost for a given system is attributed to operating and maintenance activities. [Ref. 6]

Supply Support is defined as the management actions, procedures and techniques used to determine requirements to acquire, catalog, stock, issue, and dispose of the spares, repair parts and consumables items that will be necessary to operate and maintain the weapon system during its life cycle. [Ref. 5]

As mentioned before, supply support is one of the logistics elements planned and prepared during the ILS process in the Brazilian Navy. The cost of this element has a significant impact on the source selection of the acquisition process. Just the acquisition cost of the Depot Level Repairable items analyzed in this thesis represented 24% of the total spent to acquire the helicopters they support. [Ref. 9]

During the ILS, the Program Manager develops a supply plan for the new weapon system. The main document in this plan is a list with range and depth of support items that will be necessary to acquire. The list is the base for the calculation of the supply support costs that comprise the life cycle cost of the weapon system. [Ref. 5] The Program Manager develops the list of support items based on the following information:

- A forecast of the system usage provided by the CNO office,
- If available, historical demand data from similar systems provided by the Naval Supply Command,
- Engineering and other technical information obtained from the suppliers, and
- Cost information obtained from market research or from the system supplier.

III. THE REPAIRABLE-ITEM INVENTORY SYSTEM

In Appendix A, some terms and definitions are discussed that provide the reader with fundamental information needed to better understand the material presented in this chapter. The existing system in Brazilian Navy is similar to the system used in the United States Navy. The same three levels of maintenance previously mentioned for Brazilian Navy maintenance programs are assumed. The Brazilian Navy operates helicopters produced by contractors in four different countries, i.e., the United States, England, Italy and France. Presently, due to the technological complexity, a DLR item of these helicopters that needs D-level maintenance is sent to the manufacturer in these countries to be repaired.

When a repairable item fails, a corresponding serviceable item is obtained from the rotable pool at the base and installed on the helicopter, thereby restoring it to full mission capability. These maintenance actions are considered to be at the organizational maintenance level. The failed item is submitted to the intermediate level maintenance. Some of the repairable items can be repaired in Brazil depending on the maintenance level required.

The DLR requiring depot level maintenance is forwarded to a shipping facility and from there to a contractor repair facility located in one of the countries mentioned above. Once they reach the repair facility, carcasses are scheduled for repair, and subsequently returned in serviceable condition to the rotable pool.

The cycle time from the moment that a failure is detected until the moment when the item returns to the stock point in a serviceable condition is unknown. The system does

not collect this data automatically. Long turnaround times adversely affect the readiness of helicopter squadrons.

In all the steps followed from the time of failure to the return in RFI condition at the rotable pool, the DLR experiences long LDT and ADT. These delay times are the result of a number of issues. First, there is a need to fill out forms, pack the carcass and arrange transportation to a shipping facility. Second, when shipping materials from Brazil to another country and vice versa, it is necessary to prepare the exportation forms, conduct custom inspections in Brazil and in the destination country, and track the round trip transportation time. Finally, more delay is experienced when returning a repaired item to the rotable pool in the stock point due to the transportation time and the receiving process.

Figure 3.1 shows the flow of materials through the Brazilian Navy repairable-item inventory system.

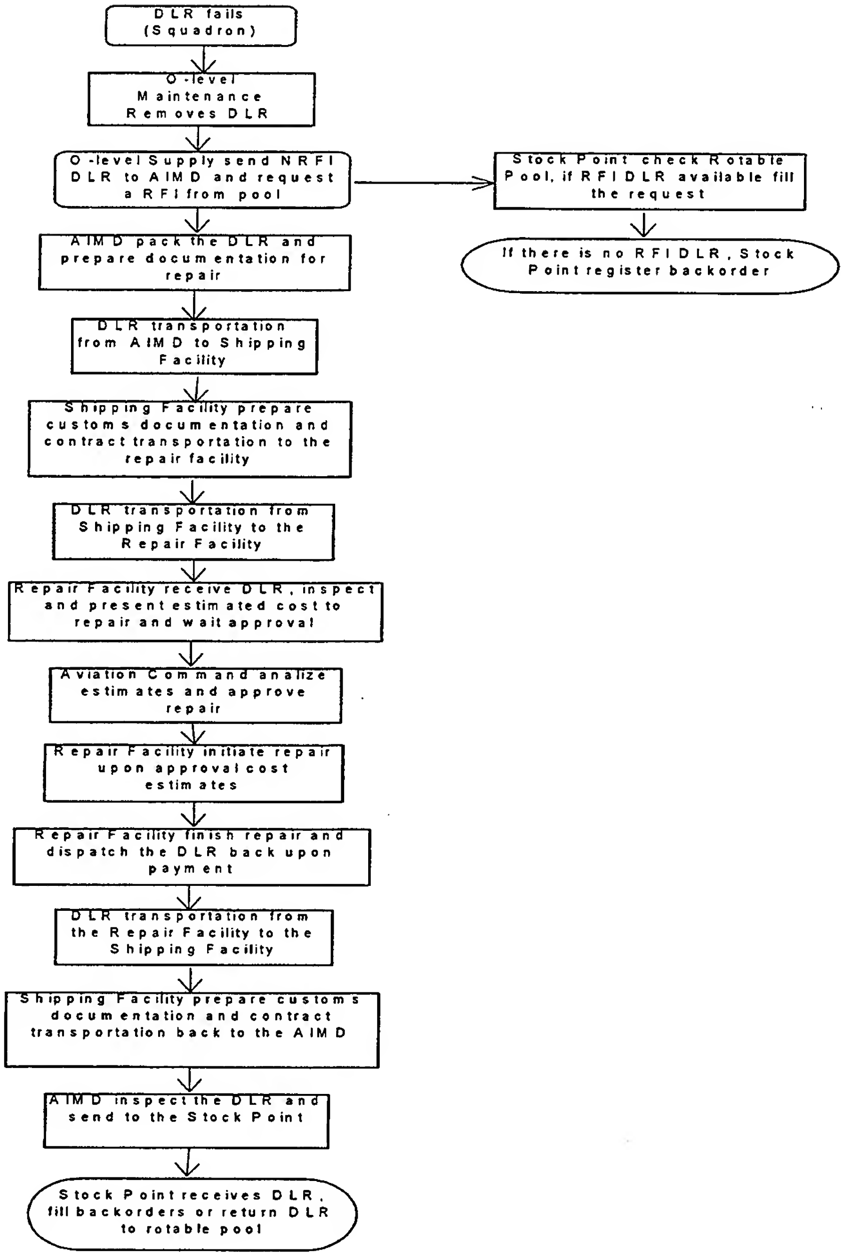

Figure 3.1. DLR Repair Cycle.

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IV. A SIMULATION MODEL

A. SIMULATION WITH ARENA

Simulation is a quantitative analysis technique in which a model of a real world situation is developed and manipulated in order to gain knowledge and draw conclusions about the real world situation. Nowadays, the proliferation of personal computers contributes to the creation and dissemination of a large number of computer simulation tools, which are largely available in the market.

To meet the objective of this thesis, a tool that not only would mimic the behavior of our real systems, but would also perform a simulation analysis was needed. Arena software, developed by Systems Modeling Corporation and Optimization Technologies, Inc., was chosen because of its powerful modeling capabilities. Arena also exploits a heritage of power simulation software in a natural, graphical interface. According to its creators, Arena enables process improvement by simulating core business functions in computer models and allows users to analyze alternative scenarios. [Ref. 10]

Our model representing the repair process of critical helicopter components was built with Arena. By using many available icons and connecting lines, it was possible to mimic the actual movement of entities through the system. With this graphic approach, the user can visualize the model as he would visualize the real system.

B. DATA SOURCES

As mentioned previously, the Brazilian Navy repairable system does not compute or collect the data necessary for the development of our thesis automatically. According to Brazilian Navy Aviation Command, some data, i.e., time to repair, time to transport,

MTBF, MTBM, etc., are registered in the documents elaborated upon during the repair process. Retrieval required an intensive effort. Other data like time to remove/install components and time to process documents have no register at all. They had to be estimated based on the experience of the personnel involved in the activity. Despite all these difficulties, the Brazilian Navy Aviation Command was able to construct the data needed for the models developed in this thesis. [Ref. 1]

C. MODEL DESCRIPTION

The information supplied from the previous chapter generated the basic scenario in which our model takes place. Now, the simulation model of the Brazilian Navy repair process will be described in more detail. There are many specific rotable pools, one for each repairable item in the helicopter. However, for the purpose for this thesis, eight specific rotable pools of DLR items, listed below, are going to analyzed. These items were selected because of their criticality for the helicopter flying mission and also because these items were responsible for 64% of the costs associated with materials sent abroad by the Brazilian Navy to Depot Level Repair. These DLR items are, [Ref. 9]

- Engine,
- Intermediate Gearbox,
- Main Rotor Head,
- Main Gearbox,
- Tail Gearbox,
- Auxiliary Servo,
- Tail Rotor Head, and
- Primary Servo.

During this simulation, the same rotable pool level was used for all the different helicopters operated by the Brazilian Navy. The purpose is not only to determine the different turn around times (TAT) faced by the repairable-item inventory system when

operating with contractors in different countries, but also to see the effect of these TAT in the operational availability of the fleet. Table 4.1 presents the existing level for each DLR rotable pool. [Ref. 1]

	Quantity
Engine	11
Intermediate Gearbox	6
Main Rotor Head	8
Main Gearbox	6
Tail Gearbox	6
Auxiliary Servo	7
Tail Rotor Head	6
Primary Servo	7

Table 4.1. DLR Rotable Pool Levels.

The average flight hour rates per helicopter observed in year 1999 was 25 hours per month on average for the Brazilian Navy fleet. [Ref. 9]

The MTBF (mean time between failures) data concerning this group of DLRs was collected manually by the Brazilian Navy Aviation Command from the logbooks of these components. [Ref. 7]

Based on the data collected by the Brazilian Navy and on the average flight hour rates, the MTBF in days was determined. The statistical distributions were determined by applying the resulting data to the data input analyzer tool in Arena.

The input analyzer tool is a standard tool that accompanies Arena and is designed to fit a distribution to observed data and measure how well it fits the data. As a result of this process, this group of DLR's appear to follow exponential distributions with MTBF as specified. Table 4.2 summarizes the result.

	MTBF (days)	**Distribution**
Engine	62.3	Exponential
Intermediate Gearbox	44.5	Exponential
Main Rotor Head	40	Exponential
Main Gearbox	41.8	Exponential
Tail Gearbox	61.5	Exponential
Auxiliary Servo	37.8	Exponential
Tail Rotor Head	32.7	Exponential
Primary Servo	36	Exponential

Table 4.2. DLRs' Mean Time Between Failures.

When a DLR fails, a RFI DLR from the rotable pool is installed. The faulty DLR becomes an input to the AIMD where it is prepared to be sent abroad for repair.

The time for removal/installation of DLR in the squadron and the preparation and transportation time from the AIMD to the shipping facility is not registered or collected by the Brazilian Navy. The data provided by the Aviation Command is based on interviews with the persons involved in the activity. [Ref. 1] The Aviation Command estimates that to perform of these activities there is a minimum, mode and maximum for the time consumed, and that some variation around the mode can be observed. Using the

data provided, a triangular distribution was selected to fit these empirical data. The triangular distribution is defined by a minimum, most likely, and maximum value, and is a natural way to estimate the time required for some activity. [Ref. 10] Table 4.3 displays these times for each DLR measured in days.

When one DLR fails, and there is no RFI DLR available from the rotable pool, the helicopter will be grounded until a RFI DLR is available.

	Time Consumed(days)
Engine	TRIA (20,30,60)
Intermediate Gearbox	TRIA (20,30,40)
Main Rotor Head	TRIA (20,30,50)
Main Gearbox	TRIA (20,30,40)
Tail Gearbox	TRIA (20,30,50)
Auxiliary Servo	TRIA (15,25,30)
Tail Rotor Head	TRIA (15,20,30)
Primary Servo	TRIA (15,25,30)

Table 4.3. DLRs' Squadron /AIMD Removal and Transportation Time.

As mentioned in the previous chapter, the Brazilian Navy does not repair helicopter DLRs. All failed units are considered beyond the capability of maintenance and are shipped abroad for repair (D-level maintenance). The Brazilian Navy uses sea transportation as the default transportation mode. The time consumed in this activity is not collected, but the Aviation Command was able to provide an estimated minimum, mode, and maximum time. Thus the triangular distribution, TRIA (80,138,311), was

selected to fit the empirical data provided by the Aviation Command. [Ref. 1] This time, expressed in days, is consumed by the shipping facility to prepare the necessary documentation and to transport the failed carcass to its destination abroad for repairing and was estimated from some of the documentation elaborated during these activities.

The time needed to repair each DLR is different for each contractor. The Aviation Command also does not collect this data regularly, but is able to provide an estimated minimum, mode and maximum time based on documents, like work orders and invoices issued during these activities. The triangular distribution was selected to fit these data. [Ref. 1]

Table 4.4. presents the total time, expressed in days, to repair each DLR by the different maintenance providers.

	United States	**France**	**England**	**Italy**
Engine	TRIA(54,60,150)	TRIA(72,80,200)	TRIA(117,130,325)	TRIA(90,100,250)
Intermediate Gearbox	TRIA(30,36,72)	TRIA(40,48,96)	TRIA(65,78,156)	TRIA(50,60,120)
Main Rotor Head	TRIA(72,84,144)	TRIA(96,112,192)	TRIA(156,182,312)	TRIA(120,140,240)
Main Gearbox	TRIA(60,84,144)	TRIA(80,112,192)	TRIA(130,182,312)	TRIA(100,140,240)
Tail Gearbox	TRIA(30,36,48)	TRIA(40,48,64)	TRIA(65,78,104)	TRIA(50,60,80)
Auxiliary Servo	TRIA(42,48,54)	TRIA(56,64,72)	TRIA(91,104,117)	TRIA(70,80,90)
Tail Rotor Head	TRIA(24,30,36)	TRIA(32,40,48)	TRIA(52,65,78)	TRIA(40,50,60)
Primary Servo	TRIA(42,48,60)	TRIA(56,64,80)	TRIA(91,104,130)	TRIA(70,80,100)

Table 4.4. Distribution of Total Time to Repair Abroad.

Appendix B includes a view of the entire simulation model logic and a static view of the animation. Notice that the model is organized in such a manner that explicitly shows the path DLRs follow during the repair process and the use of the rotable pool. There is also a section named "Control Panel" where the resources related to "data updating" and output settings are placed, as well as the representation of the rotable

pools. In this case, the model can be easily changed to respond to different "what-if" scenarios.

D. ASSUMPTIONS

The developed model intends to furnish the logistics decision makers with a decision support tool for the analysis of the operational availability of the Brazilian Navy helicopter fleet, as well as to evaluate the cost-effectiveness of the repairable-item inventory systems. On the other hand, the level of details and variations encountered when rendering an accurate simulation model had to be limited. Therefore, the following assumptions were made to use the model.

- All DLRs are serviceable i.e., no condemnations are possible,
- Spares do not fail while in the rotable pool,
- Failures are always due to one, and only one of the DLRs. Consequently, DLRs do not fail at the same time, and
- Cannibalizations are not considered. Hence, the operational availability of the fleets may be less in the simulation model than in real circumstances.

E. VALIDATION

Our simulation model replication length was set for a period equivalent to ten years because of the Brazilian Navy's assumption of a helicopter's useful life before the need to modernize the process. [Ref. 11]

Fifty replications for each of the contractors was run. This ensured a number of observations large enough for each run to provide an average operational availability value that is statistically reasonable.

Counters were placed along the model (see Appendix B). They provided accountability for the number of parts flowing through the model at any time, as well as for the number of helicopters in queue due to the limitation of DLRs in serviceable

condition. These counters are very helpful in determining the potential bottlenecks of the system.

F. RESULTS

The results from running the simulation model showed that under the same inventory level of DLR, the Brazilian Navy helicopter fleet can have an A_0 that ranges from 44 percent to 50 percent. The differences are not greater because 75% of the time necessary to return a DLR item to RFI condition is consumed by the Brazilian Navy repairable system in transportation and administrative time. [Ref. 1] Appendix C presents the corresponding simulation output. Table 4.5 summarizes the TAT measured in days that each of DLRs in this study encounters with each contractor and the A_o that the Brazilian Navy helicopter fleet achieves as a result of this TAT.

	United States TAT	France TAT	England TAT	Italy TAT
Engine	304.11	332.09	404.38	360.96
Intermediate Gearbox	261.11	276.50	314.11	291.58
Main Rotor Head	313.91	347.93	430.83	381.58
Main Gearbox	310.22	342.84	419.78	374.76
Tail Gearbox	250.64	266.00	298.83	278.88
Auxiliary Servo	264.13	278.68	319.25	296.51
Tail Rotor Head	244.62	256.08	279.85	265.32
Primary Servo	263.61	280.80	323.79	298.98
A_o	50.53%	48.30%	44.51%	46.73%

Table 4.5. Summary of Simulation Results.

Notice that there are significant differences in TAT among the maintenance providers. England has the longest time in each category because of long bureaucratic procedures imposed by the government for companies dealing with military materials from foreign countries. To a great extent these long TAT can be attributed to outdated managerial procedures of the maintenance provider. United States has the shortest time in each category because of up-to-date managerial procedures of the maintenance provider, less government intervention in the maintenance providers, and intense commercial activity between the two countries which increases the transportation availability.

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V. INVENTORY OPTIMIZATION AND OPERATIONAL AVAILABILITY

A. INVENTORY MANAGEMENT

1. Demand Based Sparing (DBS)

The traditional inventory models, also called DBS, are characterized by an item approach with a focus on consumable items. The focus of this model is on determining how many and when to order each item while trying to balance the holding, ordering and stockout costs associated with these items. Under the DBS models each item is considered independently and equally; the decision to stock one item does not affect the decision to stock other items. All items have the same importance regarding the weapon system or equipment.

The DBS models are largely used in commercial and military environments because they are relatively simple to implement based on information readily available, i.e., the past demands for the item. In the commercial world, the model works well because for a backordered item the customer can go and buy from another source or wait to receive the item. However, for military customers, this model presents two important drawbacks. First, in the military, the items are not equal. A spare can have different degrees of importance based on its effect on the system. A backordered item can mean that a complex, highly sophisticated and expensive defense system is not able to accomplish its mission and thereby causes degradation in force readiness. Second, in DBS, the system availability and the total investment in spares are outputs of the item decisions. Only after we buy each of the items that are part of the system we are able measure the resulting system availability and the total investment. Therefore, the

decisionmaker has no previous knowledge of the impact his or her decision of buying one item instead of another will have on the A_o of a system. Also, there is no way to determine what is the necessary investment to achieve a desired system A_o.

2. Readiness Based Sparing (RBS)

> The objective of RBS is to provide the range, depth and location of spare parts to support readiness objectives at the least cost given the reliability and maintainability characteristic of a system or equipment. [Ref. 12]

Contrasted with the traditional model, RBS is a different approach where the focus changes from the item to the entire system and from consumables to repairable items. The fundamental questions in this model are, "How much it will cost to obtain spares to achieve desired system availability?", and "How much do we need to move to a higher A_o?"

Consider an inventory manager deciding which of two different spares to stock, each of them having the same probability of failure and the same impact on the system A_o but with different costs. Thus, an additional unit of any of the item results in the same increase in the system availability, but each unit will have a different impact on the budget. The RBS model determines the marginal increase in operational performance per increase in unit spares cost.

The RBS model answers the questions above by presenting the decisionmaker with the system availability-cost curve as shown in Figure 5.1. The curve represents the dollar cost of incrementing the A_o. Points locate above the curve are unattainable and points below the curve represent inefficient allocation of resources. The curve gives the decision maker the ability to see the difference in costs that each level of A_o requires and how much availability can be achieved within budget constraints [Ref. 13]

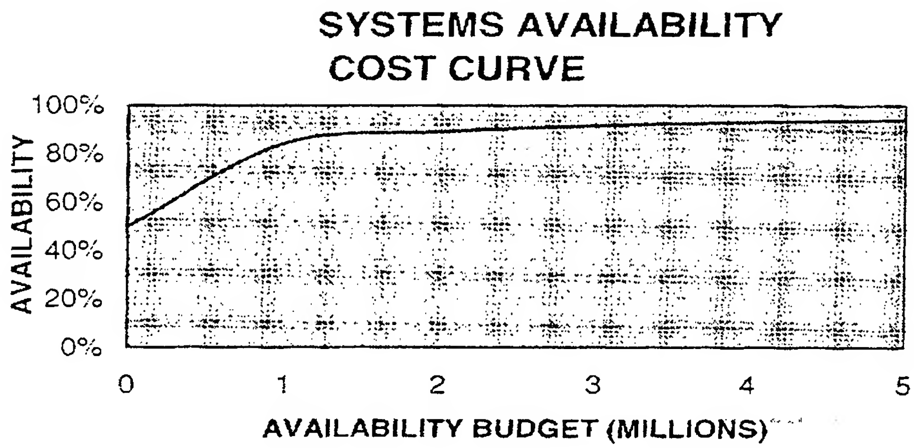

Figure 5.1 Example of System Availability Cost Curve. From Ref. [13].

3. The RBS Models

The RBS models are classified into two types: Single-Site and Multi-Echelon. The Single-Site model describes the stock selection process at a single base without considering the stock at other bases or at a Depot. The Multi-Echelon Model considers a much more complex supply/maintenance environment, where the existence of various bases and Depots must be taken into consideration when selecting stock. [Ref. 13]

In this thesis the Single-Site Model is discussed and used to find the optimal quantity of DLR that the Brazilian Navy must carry to achieve a desired A_o. This decision is based on the fact that this is the model which describes the existing structure in the Brazilian Navy where there is only one aviation base.

4. The Single-Site Model

This model seeks to maximize system availability by minimizing the expected number of backorders (EBO), which corresponds to an increase in the fill rate at the base. We call EBOs the unfilled demand existing at any point in time. The fill rate is the

percentage of demands that are met at the time of demand. It can be shown that minimizing EBO corresponds to maximizing system availability. [Ref. 13]

Then, the model uses marginal analysis to select from a group of candidates, to show which item provides the greatest contribution to the system availability at the least cost. The selection of items proceeds until it consumes the entire budget or achieves the desired availability.

The mathematical formulas of the Single-Site model is shown below:

$$s = OH + DI - BO$$

where (s) represents stock level. It is defined as the sum of the on hand inventory (OH), the quantity due in (DI), minus the number of backorders (BO). The expected fill rate (EFR) is

$$EFR(s) = Pr\ \{DI \leq s\text{-}1\}$$

For expected backorders, the probability that the number of items due in exceeds the stock level "s" is computed, or

$$EBO = \sum_{x = s+1}^{\infty} (x\text{-}s)\ Pr\ \{DI = x\}$$

In addition, for each item that is a candidate to be stocked, Δ is calculated as shown below. The marginal decrease in EBO per unit of cost (c) obtained by adding one more unit of the item is shown.

$$\Delta = \frac{EBO(s) - EBO\ (s + 1)}{c}$$

5. Assumptions

It is assumed that the time to the next DLR failure is not dependent on the time from the previous DLR failure. This characteristic is called memoryless, which is represented by the exponential distribution. When the time between failures follows the exponential distribution, then the expected number of failures over any fixed period of time follows Poisson distribution. Empirical evidence shows that the Poisson distribution is a reasonable distribution to describe the failures of repairables. [Ref. 14]

B. OPTIMIZATION OF THE BRAZILIAN NAVY'S DLR INVENTORY

The basics of RBS and the Single-Site model have been covered. This model is next applied to determine the optimal level of DLRs the Brazilian Navy has to maintain to achieve desired operational availability.

Our optimal inventory determination begins by using the TAT the DLRs experience in each country obtained from the simulation model and the DLR annual demand provided by the Brazilian Navy to determine the average pipeline inventory. Table 5.1. presents the average time period, average demand and average pipeline inventory for each DLR.

	Country	Mean annual demand (m)	Average total time (T) years	Average Pipeline u = m T
Engine	ITALY	5.7857	1.0027	5.8011
	USA	5.7857	0.8448	4.8875
	ENGLAND	5.7857	1.1233	6.4990
	FRANCE	5.7857	0.9225	5.3372
Intermediate Gearbox	ITALY	8.1000	0.8099	6.5606
	USA	8.1000	0.7253	5.8750
	ENGLAND	8.1000	0.8725	7.0675
	FRANCE	8.1000	0.7681	6.2213
Main Rotor Head	ITALY	9.0000	1.0599	9.5395
	USA	9.0000	0.8720	7.8478
	ENGLAND	9.0000	1.1968	10.7708
	FRANCE	9.0000	0.9665	8.6983
Main Gearbox	ITALY	8.6000	1.0410	8.9526
	USA	8.6000	0.8617	7.4108
	ENGLAND	8.6000	1.1661	10.0281
	FRANCE	8.6000	0.9523	8.1901
Tail Gearbox	ITALY	5.8500	0.7747	4.5318
	USA	5.8500	0.6962	4.0729
	ENGLAND	5.8500	0.8301	4.8560
	FRANCE	5.8500	0.7389	4.3225
Auxiliary Servo	ITALY	9.5000	0.8236	7.8246
	USA	9.5000	0.7337	6.9701
	ENGLAND	9.5000	0.8868	8.4247
	FRANCE	9.5000	0.7741	7.3541
Tail Rotor Head	ITALY	11.0000	0.7370	8.1070
	USA	11.0000	0.6795	7.4745
	ENGLAND	11.0000	0.7774	8.5510
	FRANCE	11.0000	0.7113	7.8247
Primary Servo	ITALY	10.0000	0.8305	8.3050
	USA	10.0000	0.7323	7.3225
	ENGLAND	10.0000	0.8999	8.9992
	FRANCE	10.0000	0.7800	7.8000

Table 5.1. Average Pipeline.

Next, the expected backorders are calculated for different stock levels using software developed by Gue (2000). [Ref. 15] The software uses this information to provide the EBO for each DLR stock level. This operation is repeated for each country where the D-level maintenance takes place. Appendix D presents the software outputs.

Then, a spreadsheet model is constructed, where the EBO information provided by the software and the DLR cost information provided by the Brazilian Navy, see Table 5.2, are the inputs. With these inputs, the decrease in EBO or Δ resulting from adding one more unit of each DLR to the inventory is calculated.

	Acquisition Cost ($ 000)
Engine	1,300
Intermediate Gearbox	143
Main Rotor Head	1,084
Main Gearbox	450
Tail Gearbox	230
Auxiliary Servo	153
Tail Rotor Head	197
Primary Servo	153

Table 5.2. Acquisition Costs of DLR.

Appendix E presents the resulting spreadsheets with the reduction of EBO corresponding to each country where the D-level maintenance of DLRs takes place.

In a next step, from the spreadsheet developed we select the DLRs that provide the greatest reduction in the EBO. The item selected is added to the inventory, and for the new stock level, we run the simulation model to measure the new A_o achieved by the system. The result is compared with the former to confirm the increase in availability and validate the optimization model.

However, as Kang et al. (1998) point out "An additional spare provides a higher A_o, but the marginal increase in A_o decreases as the number of spares increase." In our

model we observe that after achieving an operational availability of 55% additional spares only leads to a very small or sometimes, depending on the source of the helicopter, no increase in A_o. Thus, to allow the comparison between the four different maintenance providers in equal conditions, we established 55% as the A_o to be achieved. This process is repeated for each country where the Brazilian Navy repairs its DLR.

From the process above, the optimal DLR inventory levels the Brazilian Navy has to maintain to achieve the desired Ao were obtained for each country. Table 5.3. summarizes the optimal inventory level for each country and the achieved A_o.

	United States	**France**	**England**	**Italy**
Engine	6	7	8	7
Intermediate Gearbox	11	11	13	12
Main Rotor Head	10	11	13	12
Main Gearbox	11	12	15	13
Tail Gearbox	7	8	9	8
Auxiliary Servo	12	13	14	13
Tail Rotor Head	12	13	14	13
Primary Servo	12	13	15	14
A_o	55.01%	55.56%	55.20%	55.32%

Table 5.3. DLR Optimal Inventory Level.

In Appendix F, all the inventory level combinations tested and the A_o achieved from running the simulation model fifty replications at each level to diminish the random effects are presented.

As all the other factors in the simulation and optimization process are held constant, it can be seen from the results summarized above that the Brazilian Navy

Helicopter fleet achieves approximately the same A_o at different inventory levels. This results from the difference in the TAT the Brazilian Navy repairable-item inventory system faces in dealing with contractors located in different countries.

C. INVENTORY LEVEL AND COSTS

Table 5.4 summarizes the different inventory levels required to achieve an A_o of 55%, the total acquisition costs of this inventory and the percentage of variation in levels and costs for each of the Brazilian Navy helicopter's source.

	USA		France		Italy		England	
Component	Inventory Level	Inventory Costs	Inventory Level	Inventory Costs	nventory Level	Inventory Costs	Inventory Level	Inventory Costs
Engine	6	$7,800,000	7	$9,100,000	7	$9,100,000	8	$10,400,000
Int. Gearbox	11	$1,573,000	11	$1,573,000	12	$1,716,000	13	$1,859,000
Main R. Head	10	$10,840,000	11	$11,924,000	12	$13,008,000	13	$14,092,000
Main Gearbox	11	$4,950,000	12	$5,400,000	13	$5,850,000	15	$6,750,000
Tail Gearbox	7	$1,610,000	8	$1,840,000	8	$1,840,000	9	$2,070,000
Aux.Servo	12	$1,836,000	13	$1,989,000	13	$1,989,000	14	$2,142,000
Tail R. Head	12	$2,364,000	13	$2,561,000	13	$2,561,000	14	$2,758,000
Primary Servo	12	$1,836,000	13	$1,989,000	14	$2,142,000	15	$2,295,000
Totals	81	$32,809,000	88	$36,376,000	92	$38,206,000	101	$42,366,000
Variation			8.64%	10.87%	13.58%	16.45%	24.69%	29.13%

Table 5.4. Inventory Level and Costs.

The comparison between each source shows that the Brazilian Navy experiences an increase in inventory levels that ranges from 8.64% to 24.69% and from 10.87% to 29.13% in inventory costs.

D. LIFE CYCLE COST OF DLR INVENTORY

The dollar value presented in Figure 5.4 represents the Brazilian Navy's initial outfitting cost of DLR inventory. The cost of the capital used to build these inventory levels also needs to be computed during the useful life of the helicopter which is deviated from other uses in the Navy. [Ref. 16] As the Brazilian Navy does not have a specific discount rate to evaluate investment in projects, a 10% discount rate was adopted, which is the rate determined by the U.S. Office of Management and Budget for evaluation of all

the Federal Government projects. This rate is used to determine the total life cycle cost of the different inventory levels. [Ref. 16]

The period of investment is the same period assumed by the Brazilian Navy as the useful life of a helicopter, or 10 years. [Ref. 11]

Then, the information above is used to calculate the Future Value of the difference in inventory cost. The F_n mathematical formula is: [Ref. 17]

$$F_n = P\,(1 + r)^n,$$

where:

F_n = accumulation or future value

P = one-time investment today

R = interest rate per period

n = number of periods

Table 5.5 presents the F_n results obtained from a spreadsheet model.

Source Country	**Difference (US$)**	**Value in 10years (US$)**
USA	-	-
France	$3,567,000	$9,251,879
Italy	$5,397,000	$13,998,428
England	$9,557,000	$24,788,397

Table 5.5. Life Cycle Inventory Cost.

VI. CONCLUSIONS AND RECOMMENDATIONS

The initial chapters were devoted to the introduction of the Brazilian Navy Acquisition System and repairable-item inventory systems. A simulation model to mimic the repair process of a selected group of critical DLR components was then developed. The TAT of this group of critical DLR under each of the repair facilities used by the Brazilian Navy was measured. Then, we found the optimal inventory level the Brazilian Navy has to maintain in order to achieve a desired A_0 under the TAT faced by the system. We showed that the optimal inventory level necessary to achieve the desired A_0 varies depending on the source of the helicopter. Furthermore, the variation in inventory levels has a significant impact on inventory costs which are not taken into consideration by the Brazilian Navy during the source selection in the acquisition system.

A. CONCLUSIONS

The following are specific conclusions drawn from our study:

Source selection in the Brazilian Navy acquisition system does not take into account the variation in DLR inventory levels and related costs, which results from the different TAT faced by the repairable-item inventory system when dealing with each source. As the Brazilian Navy acquires its DLR items, cost analysis evaluating the supply support needed by the helicopter of each source is based only on the difference in the initial costs of these materials, which often results in buying from a source with the lowest price. However, depending on TAT of the source, the initial low price can be more expensive due to larger inventories needed to account for repair turnaround time.

The difference in DLR inventory levels from one source to another can lead to an increase in the inventory costs from $9.2 million to $24.7 million dollars. Considering that the average acquisition cost of one of the helicopters operated by the Brazilian Navy is approximately $3.4 million, the difference in inventory costs can represent the acquisition of almost five new helicopters, a significant increase in the helicopter fleet.

The source of the helicopter repair also greatly influences operational availability. In the current scenario where the Brazilian Navy operates helicopters from four different sources, the variation in operational availability ranges from 44 to 50 percent depending on the helicopter source, assuming existing rotable pool inventories. This represents an average of 4 more helicopters available over a period of ten years, with a lower inventory level and cost.

In the Brazilian Navy repairable-item inventory system, the issue responsible for the majority of the long TAT is the system itself. The system consumes 75% of the TAT with ADT and LDT. The main cause is the use of the sea transportation mode.

B. RECOMMENDATIONS

The lessons learned from the analyses conducted in this thesis support the following recommendations:

The Brazilian Navy should consider using the methodology presented in this thesis during the acquisition of new weapons system to evaluate the impact that each of the possible sources will have on inventory levels and costs. This will bring economical advantage by offering the possibility of selecting a source that requires lower inventory levels and costs.

The Brazilian Navy should consider the use of simulation models like the one developed in this thesis during new weapons systems acquisition process to evaluate the impact of the TAT of different sources will have on operational availability of the new system. This brings operational advantages to the Navy by having more systems available.

The Brazilian Navy should consider implementing a mechanism that permits a continuous evaluation of the TAT in the repairable-item inventory system. This will allow preventative measures to avoid the actual "status-quo" where the system itself is responsible for the largest part of the TAT with adverse effects on inventories and operational availability.

DLRs are critical and expensive components that must be closely tracked and have their related data automatically and accurately recorded. Historical data collection of Mean Time Between Failures, Mean Time To Repair and so on, become fundamental at the time of using methodologies such as the one presented in this thesis. Difficulties were encountered during our data collection from the Brazilian Navy because the data needed to be collected manually and was not always available. Different explanations were given such as lack of personnel, lack of resources, poor managerial tools and organizational cultural reasons. The Brazilian Navy should consider the implementation of the computer systems that support its repairable-item inventory system of databases that allow the automatic collection and storage of this information.

C. SUGGESTED TOPICS FOR FURTHER RESEARCH

The Brazilian law establishes that government agencies must evaluate the costs when acquiring supplies and services. The Brazilian Navy option for sea mode is the

result of contracting transportation based only on the lowest price offered. As we show in the thesis the transportation of components to Depot Level Maintenance is a major contributor to long TAT in the repairable-item inventory system, which results in bigger inventory levels and costs for the Brazilian Navy, these factors are not taken into consideration when contracting the material transportation. We recommend a cost benefit analysis of this option and a comparison with the use of air mode as the default way to ship critical components.

APPENDIX A. DEFINITIONS AND ESSENTIAL TERMS

DEFINITIONS AND ESSENTIAL TERMS

1. Repairable Item

A repairable is a supply item that is subject to economical repair and for which the repair is considered when computing requirements. [Ref. 18]

2. Repairable-Item Inventory System

A repairable-item inventory system is a set of organizations and processes used for controlling the repairable items from the point in time they fail until they return to a stock point in "ready-for-issue"(RFI) condition. In the military environment, a standard military repairable-item inventory system consists of repair facility (depot) dedicated to support one or more locations (bases) where equipment (helicopter) is assigned.

3. Levels of Maintenance

"Maintenance level pertains to the division of functions and tasks for each area where maintenance is performed." [Ref. 6:p. 116]

According to Blanchard [Ref. 6], there may be two, three, or even four levels of maintenance depending on the nature and mission of the system. This study is focused on a three-level maintenance concept, in which maintenance may be classified as *organizational, intermediate* or *depot.*

Organizational level maintenance, or O-level maintenance, is performed at the operational site (squadron). Basically, it involves tasks related to the support of its own operation, and the removed components are normally forwarded to the intermediate level.

At the Intermediate level maintenance, or I-level maintenance, the removal and replacement of major modules, assemblies or piece parts may repair end items. For instance, this is the kind of maintenance performed by Aircraft Intermediate Maintenance Departments (AIMD) ashore or afloat in aircraft carriers.

Finally, the Depot level maintenance, or D-level maintenance, constitutes the highest type of maintenance. Also called supplier or manufacture's maintenance, this level of maintenance supports 0- and I-level activities. Thus, tasks accomplished here include performing maintenance beyond the capabilities of those two previous levels. In general, the depot facilities are remotely located to support specific geographical area needs or designated product lines.

4. DLR (Depot Level Repairable)

A Depot Level Repairable is a repairable item of supply that is designated for repair at the depot level due to its complexity. Examples of DLR are engines, main gearboxes, main rotor heads and so on. [Ref. 18]

5. Rotable Pool

A rotable pool (RP) is a stockpile of repairable items that provides a spare in serviceable condition to facilitate a quick repair of a faulty system. Therefore, whenever there is a faulty component, an RFI from the pool can be quickly installed in the helicopter without waiting for the actual faulty repairable to be repaired.

6. Operational Availability

One of the major grading criteria for a Naval helicopter squadron Commander is the availability or operational readiness of the squadron. Operational Availability, commonly referred to as "Ao", is a good measure of system readiness and the essential

performance parameter of a logistics support system. Here is Blanchard's definition of Ao:

> Operational availability is the probability that a system or equipment, when used under stated conditions in an actual operational environment will operate satisfactorily when called upon. [Ref. 6:p. 81]

Operational availability, Ao, is expressed mathematically as:

$$\mathbf{A_0 = MTBM / (MTBM + MDT)}$$

Where:

- **MTBM** (mean time between maintenance) = **1/ ($MTBM_p$ + $MTBM_c$)** (or $1/(1/\lambda + 1/ftp)$ where λ is failure rate and ftp is preventive maintenance rate).

- **MDT** (maintenance down time) = **M + LDT + ADT** is total elapsed time required to repair and restore a system to full operating status.

- **M** (mean active maintenance) = mean or average elapsed time required to perform scheduled (preventive) and unscheduled (corrective) maintenance.

- **LDT** (logistics delay time) = maintenance downtime expended waiting for spare part to become available, waiting for transportation, waiting to use maintenance facility, etc.

- **ADT** (administrative delay time) = maintenance delayed for reasons of an administrative nature.

Therefore, a direct relation can be seen showing that whenever the MDT is reduced, A_o increases.

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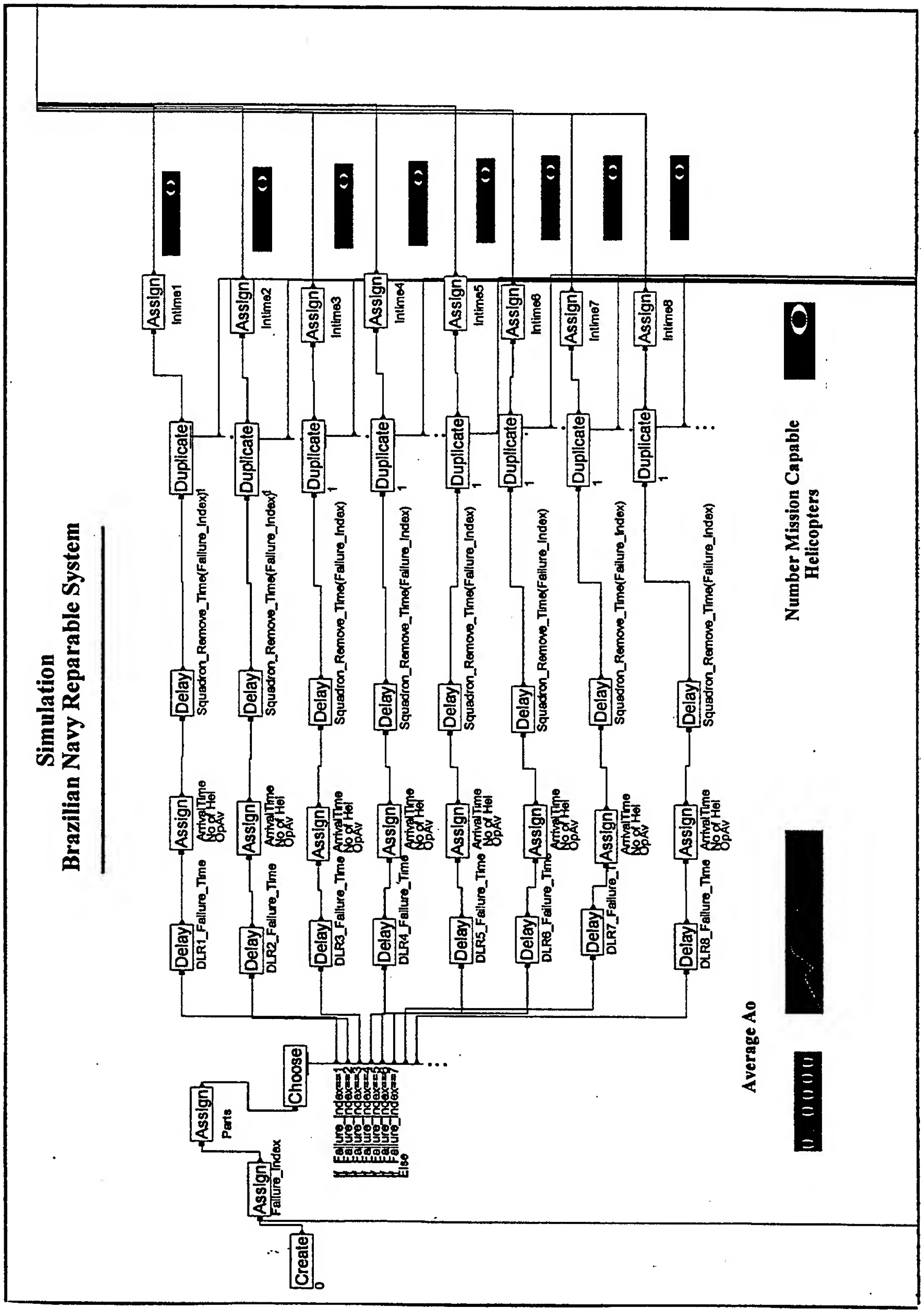
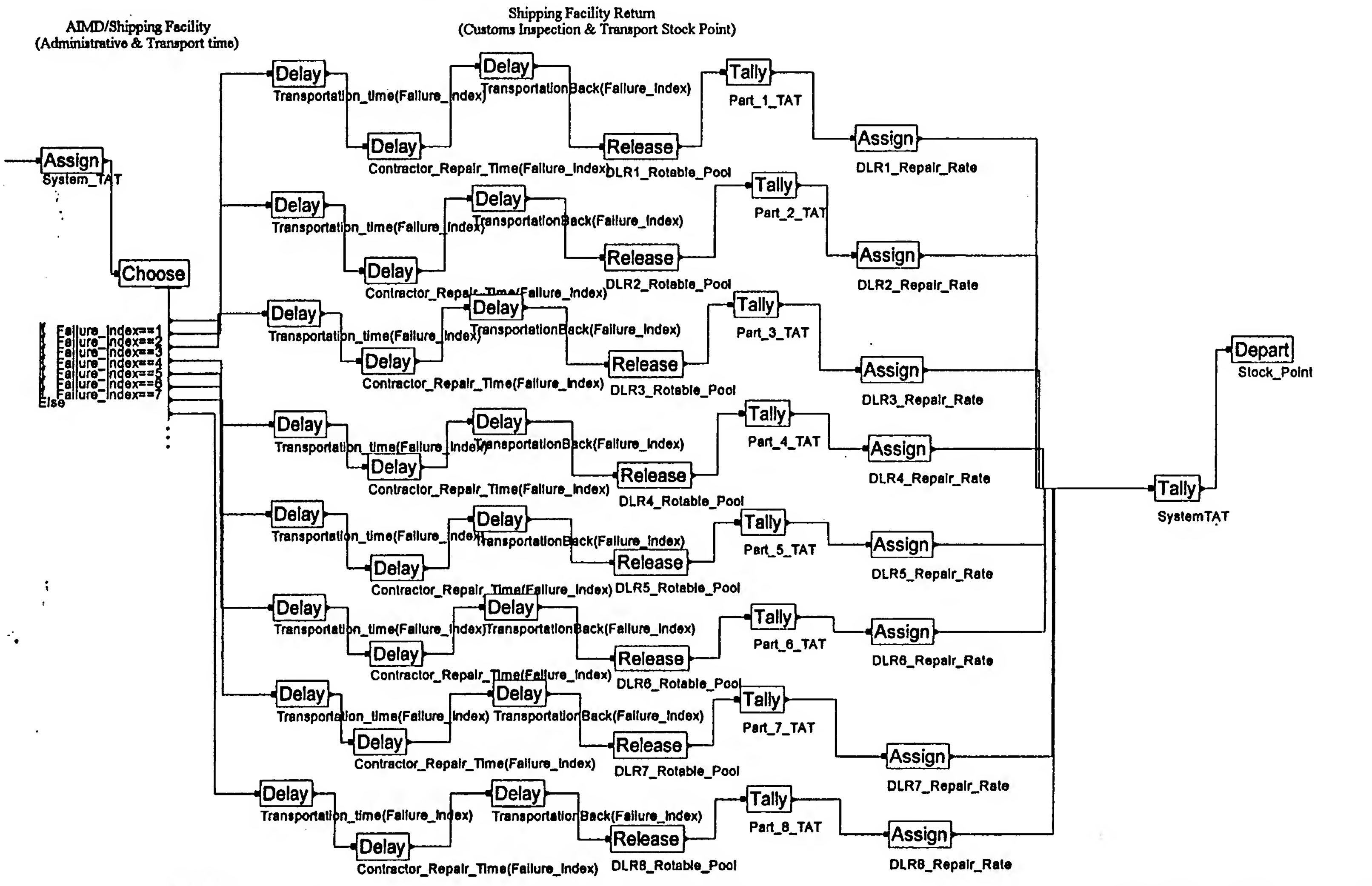
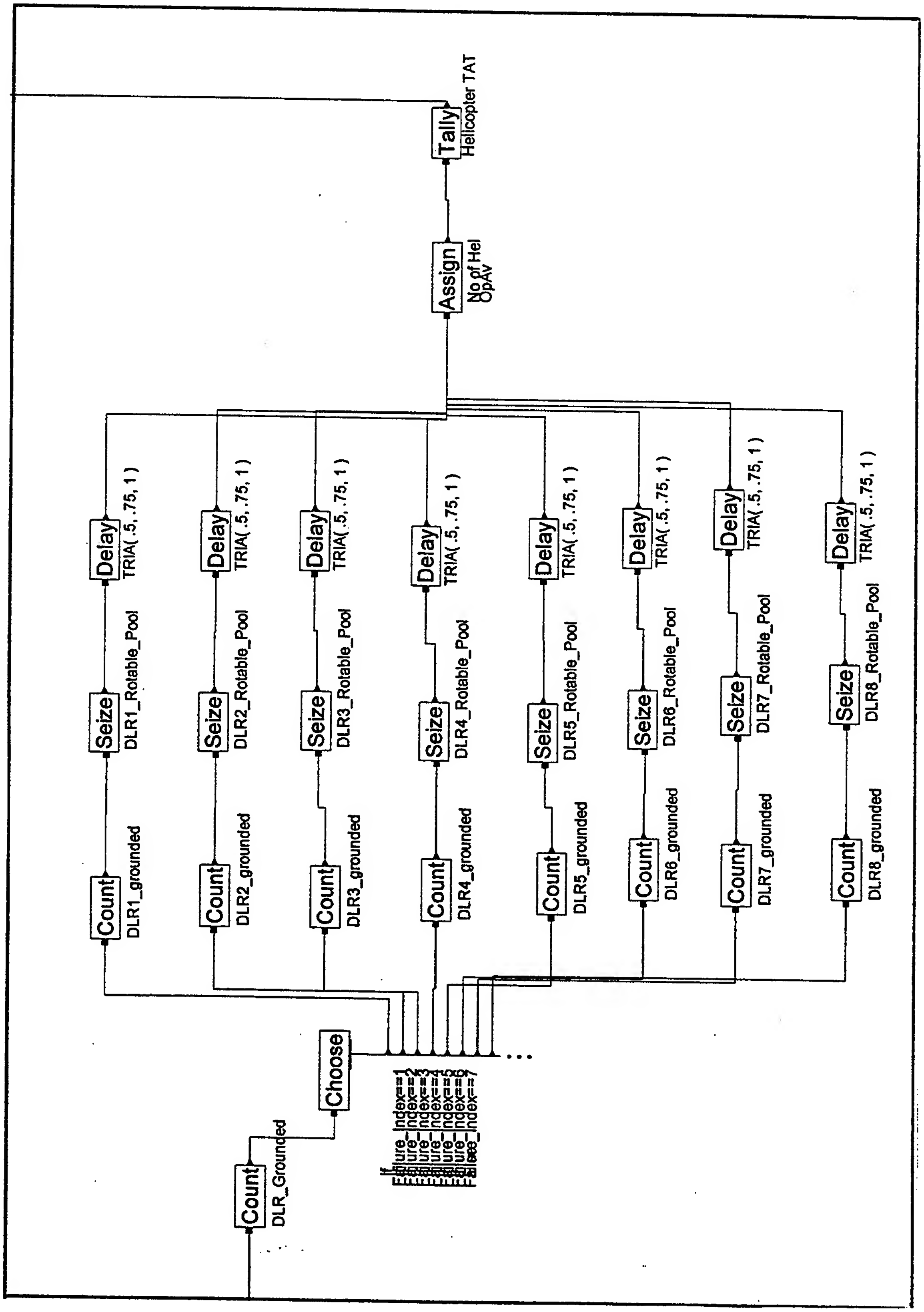
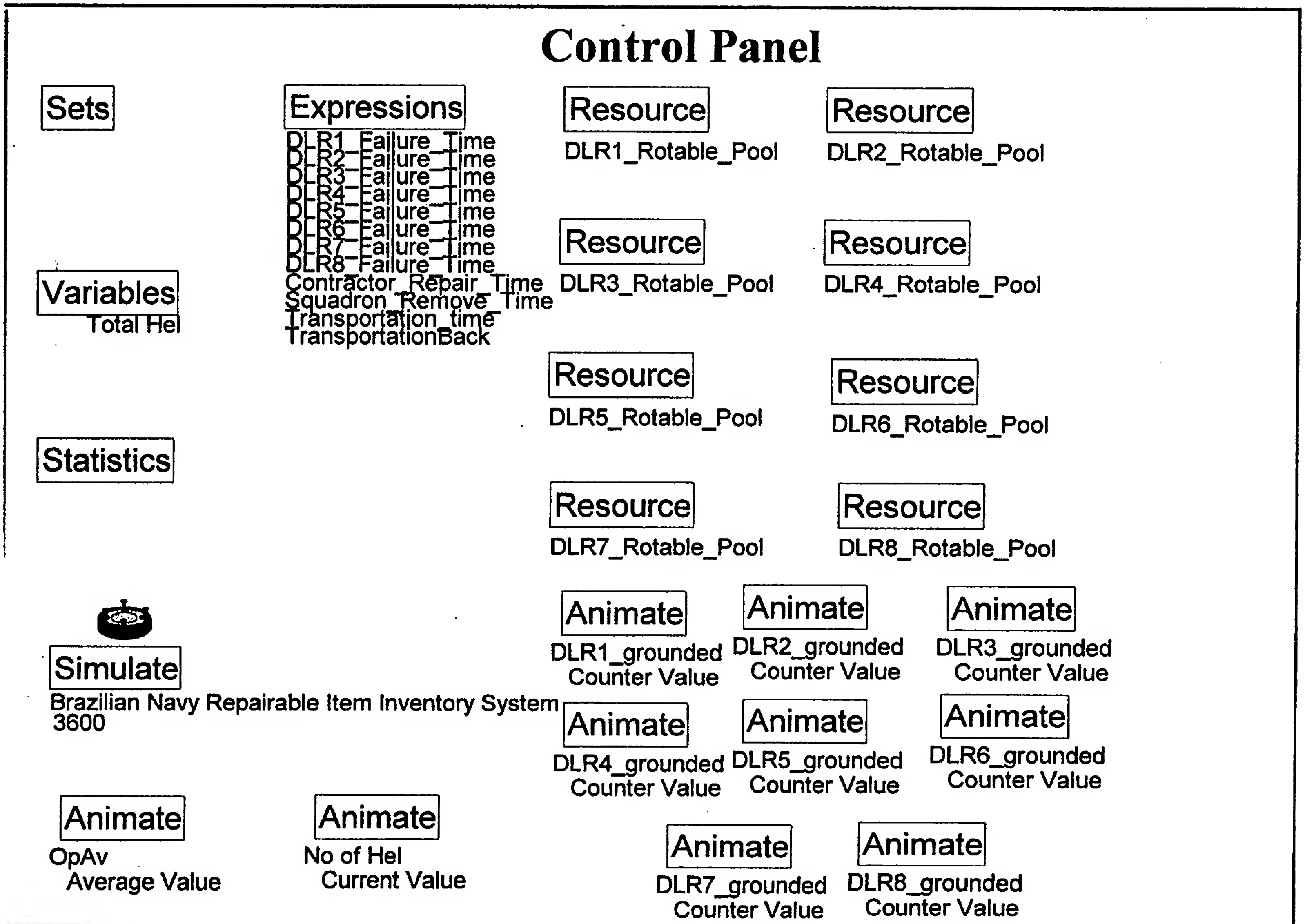
APPENDIX B. SIMULATION MODEL



Depot Level Facility
(time to repair)




Count
DLR_Grounded
Choose
If Failure_Index==1
Failure_Index==2
Failure_Index==3
Failure_Index==4
Failure_Index==5
Failure_Index==6
Failure_Index==7
Else
Count
DLR1_grounded
Seize
DLR1_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Count
DLR2_grounded
Seize
DLR2_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Count
DLR3_grounded
Seize
DLR3_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Count
DLR4_grounded
Seize
DLR4_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Count
DLR5_grounded
Seize
DLR5_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Count
DLR6_grounded
Seize
DLR6_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Count
DLR7_grounded
Seize
DLR7_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Count
DLR8_grounded
Seize
DLR8_Rotable_Pool
Delay
TRIA(.5, .75, 1)
Assign
No of Hel OpAV
Tally
Helicopter TAT


Control Panel
Sets
Expressions
DLR1_Failure_Time
DLR2_Failure_Time
DLR3_Failure_Time
DLR4_Failure_Time
DLR5_Failure_Time
DLR6_Failure_Time
DLR7_Failure_Time
DLR8_Failure_Time
Contractor_Repair_Time
Squadron_Remove_Time
Transportation_time
TransportationBack
Resource
DLR1_Rotable_Pool
Resource
DLR2_Rotable_Pool
Resource
DLR3_Rotable_Pool
Resource
DLR4_Rotable_Pool
Resource
DLR5_Rotable_Pool
Resource
DLR6_Rotable_Pool
Resource
DLR7_Rotable_Pool
Resource
DLR8_Rotable_Pool
Variables
Total Hel
Statistics
Simulate
Brazilian Navy Repairable Item Inventory System
3600
Animate
DLR1_grounded
Counter Value
Animate
DLR2_grounded
Counter Value
Animate
DLR3_grounded
Counter Value
Animate
DLR4_grounded
Counter Value
Animate
DLR5_grounded
Counter Value
Animate
DLR6_grounded
Counter Value
Animate
OpAv
Average Value
Animate
No of Hel
Current Value
Animate
DLR7_grounded
Counter Value
Animate
DLR8_grounded
Counter Value

APPENDIX C. SIMULATION OUTPUT

ARENA Simulation Results
Mauricio Casagrande - License #9400000

Output Summary for 50 Replications

Project: Brazilian Navy R/Run execution date: 10/30/2000
Analyst: Cmdr.Mauricio CA/Model revision date: 9/29/2000

OUTPUTS-USA

Identifier	Average	Half-width	Minimum	Maximum	# Replic.
Average Ao	.50537	.00620	.46836	.56218	50
Avg Helicopter TAT	44.019	.59425	39.158	48.395	50
Avg USA TAT	305.16	.78328	298.20	310.90	50
DLR_8_TAT	263.61	2.2642	246.67	278.71	50
DLR_7_TAT	244.62	1.7170	234.45	258.05	50
DLR_6_TAT	264.13	1.7211	248.13	280.76	50
DLR_5_TAT	250.64	1.3626	242.03	260.72	50
DLR_4_TAT	310.22	1.5611	297.29	326.26	50
DLR_3_TAT	313.91	1.6944	302.90	331.30	50
DLR_2_TAT	261.11	1.7509	247.18	274.39	50
DLR_1_TAT	304.11	1.8270	286.13	316.10	50

OUTPUTS-France

Identifier	Average	Half-width	Minimum	Maximum	# Replic.
Average Ao	.48302	.00588	.42196	.51269	50
Avg Helicopter TAT	47.699	.84782	43.507	57.078	50
Avg France TAT	325.98	.93005	317.34	332.68	50
DLR_8_TAT	280.80	1.8180	268.56	293.42	50
DLR_7_TAT	256.08	1.9386	241.11	272.72	50
DLR_6_TAT	278.68	2.2018	255.79	292.53	50
DLR_5_TAT	266.00	1.7366	255.30	278.59	50
DLR_4_TAT	342.84	2.1860	323.46	364.85	50
DLR_3_TAT	347.93	1.9950	332.97	360.94	50
DLR_2_TAT	276.50	1.7932	265.17	288.92	50
DLR_1_TAT	332.09	2.0524	319.27	350.97	50

OUTPUTS-England

Identifier	Average	Half-width	Minimum	Maximum	# Replic.
Average Ao	.44517	.00625	.39282	.49136	50
Avg England TAT	376.37	.98768	368.93	384.78	50
Avg Helicopter TAT	55.655	.77888	49.780	61.420	50
DLR_8_TAT	323.97	1.9180	304.08	337.60	50
DLR_7_TAT	279.85	1.8303	264.78	291.32	50
DLR_6_TAT	319.25	1.6379	309.95	333.20	50
DLR_5_TAT	298.83	1.5193	288.33	310.58	50
DLR_4_TAT	419.78	2.2111	401.62	437.43	50
DLR_3_TAT	430.83	2.5348	411.52	457.70	50
DLR_2_TAT	314.11	2.0214	294.43	328.58	50
DLR_1_TAT	404.38	2.7668	383.99	423.01	50

OUTPUTS-Italy

Identifier	Average	Half-width	Minimum	Maximum	# Replic.
Average Ao	.46739	.00526	.42460	.50280	50
Avg Helicopter TAT	50.666	.70144	46.934	57.053	50
Avg Italy TAT	346.62	.96323	338.53	352.83	50
DLR_8_TAT	298.98	1.6813	284.04	314.04	50
DLR_7_TAT	265.32	1.7258	254.77	278.68	50
DLR_6_TAT	296.51	1.8053	282.86	309.36	50
DLR_5_TAT	278.88	1.5811	268.13	294.31	50
DLR_4_TAT	374.76	1.7064	364.07	385.24	50
DLR_3_TAT	381.58	2.3165	363.63	394.89	50
DLR_2_TAT	291.58	1.6375	277.91	305.84	50
DLR_1_TAT	360.96	2.6237	340.20	383.74	50

APPENDIX D. STOCK LEVEL AND EXPECTED BACKORDERS

Italy

Inventory Level	Engine	Intemediate Gearbox	Main Rotor Head	Main Gearbox	Tail Gearbox	Auxiliary Servo	Tail Rotor Head	Primary Servo
s	EBO	EBO	EBO	EBO	EBO	EBO	EBO	EBO
0	5.801100	6.560600	9.539500	8.952600	4.531800	7.824600	8.107000	8.305000
1	4.804100	5.562000	8.539600	7.952700	3.542600	6.825000	7.107300	7.305200
2	3.824700	4.572700	7.540300	6.954000	2.602100	5.828500	6.110000	6.307500
3	2.896100	3.613900	6.544400	5.960500	1.772100	4.844300	5.122700	5.318400
4	2.066000	2.721600	5.558800	4.982400	1.109100	3.892000	4.162100	4.352800
5	1.378600	1.938600	4.598100	4.039000	0.635200	3.002100	3.255800	3.436300
6	0.856700	1.298900	3.684700	3.157600	0.332600	2.209900	2.437400	2.601100
7	0.494900	0.815900	2.846700	2.368800	0.159600	1.545200	1.737900	1.878700
8	0.265800	0.479800	2.111300	1.698200	0.070400	1.022900	1.176000	1.289900
9	0.132900	0.264100	1.498200	1.160100	0.028600	0.639900	0.753600	0.840000
10	0.062000	0.136200	1.014900	0.753800	0.010800	0.378100	0.456900	0.518100
11	0.027000	0.065900	0.655400	0.465400	0.003800	0.211000	0.262000	0.302600
12	0.011000	0.030000	0.403100	0.273000	0.001200	0.111300	0.142200	0.167400
13	0.004200	0.012900	0.236200	0.152200	0.000400	0.055600	0.073100	0.087800
14	0.001500	0.005200	0.131900	0.080700	0.000100	0.026300	0.035700	0.043700
15	0.000500	0.002000	0.070200	0.040700	0.000000	0.011800	0.016500	0.020700
16	0.000200	0.000700	0.035700	0.019600	0.000000	0.005000	0.007300	0.009300
17	0.000100	0.000300	0.017300	0.009000	0.000000	0.002100	0.003100	0.004000
18	0.000000	0.000100	0.008100	0.004000	0.000000	0.000800	0.001200	0.001600
19	0.000000	0.000000	0.003600	0.001700	0.000000	0.000300	0.000500	0.000600
20	0.000000	0.000000	0.001500	0.000700	0.000000	0.000100	0.000200	0.000200

United States

Inventory Level	Engine	Intemediate Gearbox	Main Rotor Head	Main Gearbox	Tail Gearbox	Auxiliary Servo	Tail Rotor Head	Primary Servo
s	EBO	EBO	EBO	EBO	EBO	EBO	EBO	EBO
0	4.887500	5.875000	7.847800	7.410800	4.072900	6.970100	7.474500	7.322500
1	3.895000	4.877800	6.848200	6.411400	3.089900	5.971000	6.475100	6.323200
2	2.939400	3.897100	5.851600	5.416500	2.176300	4.978500	5.479900	5.328700
3	2.073900	2.964900	4.867100	4.438200	1.403900	4.008800	4.500500	4.351900
4	1.355100	2.127600	3.914100	3.500900	0.823300	3.092200	3.560700	3.418300
5	0.815500	1.429800	3.022800	2.639600	0.437900	2.267900	2.694600	2.563800
6	0.451200	0.895700	2.228300	1.890900	0.211500	1.572500	1.938800	1.825300
7	0.229600	0.522100	1.560700	1.281400	0.093100	1.026600	1.320500	1.228100
8	0.107800	0.283100	1.035100	0.819100	0.037500	0.629800	0.848900	0.778900
9	0.046800	0.143000	0.648800	0.493300	0.013900	0.362800	0.514300	0.465100
10	0.018800	0.067400	0.384200	0.279800	0.004800	0.196300	0.293700	0.261400
11	0.007100	0.029700	0.214900	0.149600	0.001500	0.099900	0.158100	0.138400
12	0.002500	0.012300	0.113600	0.075500	0.000400	0.047900	0.080300	0.069200
13	0.000800	0.004800	0.056900	0.036000	0.000100	0.021700	0.038600	0.032600
14	0.000300	0.001800	0.027000	0.016200	0.000000	0.009300	0.017500	0.014600
15	0.000100	0.000600	0.012200	0.007000	0.000000	0.003800	0.007600	0.006200
16	0.000000	0.000200	0.005200	0.002800	0.000000	0.001400	0.003100	0.002500
17	0.000000	0.000100	0.002100	0.001100	0.000000	0.000500	0.001200	0.001000
18	0.000000	0.000000	0.000800	0.000400	0.000000	0.000200	0.000500	0.000300
19	0.000000	0.000000	0.000300	0.000100	0.000000	0.000100	0.000200	0.000100
20	0.000000	0.000000	0.000100	0.000000	0.000000	0.000000	0.000100	0.000000

England

Inventory Level	Engine	Intemediate Gearbox	Main Rotor Head	Main Gearbox	Tail Gearbox	Auxiliary Servo	Tail Rotor Head	Primary Servo
s	EBO	EBO	EBO	EBO	EBO	EBO	EBO	EBO
0	6.499000	7.067500	10.770800	10.028100	4.856000	8.424700	8.551000	8.999200
1	5.500500	6.068400	9.770800	9.028100	3.863800	7.424900	7.551200	7.999300
2	4.511800	5.075200	8.771100	8.028600	2.909400	6.427000	6.553000	7.000600
3	3.554900	4.103400	7.772500	7.031300	2.046700	5.436800	5.562000	6.006800
4	2.666800	3.181700	6.778400	6.041500	1.332500	4.468600	4.591000	5.028000
5	1.890600	2.348600	5.796000	5.070200	0.798600	3.546300	3.663200	4.083000
6	1.259700	1.640800	4.839000	4.136200	0.439800	2.701700	2.809000	3.198800
7	0.786400	1.080500	3.927500	3.264600	0.222700	1.966000	2.059700	2.405600
8	0.459300	0.669200	3.086100	2.482300	0.104000	1.361400	1.438800	1.729600
9	0.251000	0.389400	2.339100	1.812000	0.044900	0.894900	0.954900	1.185400
10	0.128500	0.213000	1.705000	1.266400	0.018000	0.557600	0.601200	0.772900
11	0.061700	0.109600	1.192500	0.845900	0.006700	0.329200	0.358900	0.479000
12	0.027900	0.053200	0.799100	0.539500	0.002300	0.184200	0.203200	0.282000
13	0.011900	0.024300	0.512600	0.328400	0.000800	0.097800	0.109200	0.157900
14	0.004800	0.010500	0.314700	0.190800	0.000200	0.049300	0.055700	0.084100
15	0.001800	0.004300	0.184900	0.105800	0.000100	0.023600	0.027000	0.042600
16	0.000700	0.001700	0.104000	0.056100	0.000000	0.010800	0.012500	0.020600
17	0.000200	0.000600	0.056000	0.028500	0.000000	0.004700	0.005500	0.009500
18	0.000100	0.000200	0.029000	0.013800	0.000000	0.001900	0.002300	0.004200
19	0.000000	0.000100	0.014400	0.006400	0.000000	0.000800	0.000900	0.001800
20	0.000000	0.000000	0.006800	0.002900	0.000000	0.000300	0.000400	0.000700

France

Inventory Level	Engine	Intemediate Gearbox	Main Rotor Head	Main Gearbox	Tail Gearbox	Auxiliary Servo	Tail Rotor Head	Primary Servo
s	EBO	EBO	EBO	EBO	EBO	EBO	EBO	EBO
0	5.337200	6.221300	8.698300	8.190100	4.322500	7.354100	7.824700	7.800000
1	4.342000	5.223300	7.698500	7.190400	3.335800	6.354700	6.825100	6.800400
2	3.372500	4.237600	6.700100	6.192900	2.406400	5.360100	5.828600	5.804000
3	2.471500	3.290400	5.708000	5.204800	1.600900	4.382700	4.844400	4.820100
4	1.692300	2.422900	4.734300	4.242000	0.974000	3.447800	3.892100	3.868600
5	1.075700	1.679500	3.800300	3.331300	0.540100	2.590900	3.002200	2.980200
6	0.632800	1.090300	2.935600	2.505700	0.273100	1.848700	2.210000	2.190500
7	0.344200	0.661100	2.171200	1.796400	0.126200	1.247100	1.545300	1.528900
8	0.173300	0.374100	1.531600	1.223200	0.053500	0.793200	1.023000	1.010100
9	0.080900	0.197700	1.027600	0.789200	0.020900	0.475100	0.640000	0.630500
10	0.035200	0.097700	0.654700	0.482000	0.007500	0.267900	0.378100	0.371600
11	0.014300	0.045200	0.395800	0.278600	0.002500	0.142400	0.211000	0.206900
12	0.005400	0.019700	0.227100	0.152400	0.000800	0.071400	0.111300	0.108800
13	0.001900	0.008000	0.123700	0.079100	0.000200	0.033800	0.055600	0.054200
14	0.000600	0.003100	0.064000	0.038900	0.000100	0.015200	0.026300	0.025600
15	0.000200	0.001100	0.031500	0.018200	0.000000	0.006400	0.011800	0.011500
16	0.000100	0.000400	0.014800	0.008100	0.000000	0.002600	0.005000	0.004900
17	0.000000	0.000100	0.006600	0.003400	0.000000	0.001000	0.002100	0.002000
18	0.000000	0.000000	0.002800	0.001400	0.000000	0.000400	0.000800	0.000800
19	0.000000	0.000000	0.001200	0.000500	0.000000	0.000100	0.000300	0.000300
20	0.000000	0.000000	0.000500	0.000200	0.000000	0.000000	0.000100	0.000100

APPENDIX E. SPREADSHEET MODEL FOR Δ CALCULATION

Marginal Decrease in EBO for Italian Helicopters

	Engine		Int. Gearbox		Main R. Head		Main Gearbox		Tail Gearbox		Aux. Servo		Tail Rot.Head		Primary Servo	
s	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ
0	5.801100		6.560600		9.539500		8.952600		4.531800		7.824600		8.107000		8.305000	
1	4.804100	0.000767	5.562000	0.006983	8.539600	0.000922	7.952700	0.002222	3.542600	0.004301	6.825000	0.006533	7.107300	0.005075	7.305200	0.006535
2	3.824700	0.000753	4.572700	0.006918	7.540300	0.000922	6.954000	0.002219	2.602100	0.004089	5.828500	0.006513	6.110000	0.005062	6.307500	0.006521
3	2.896100	0.000714	3.613900	0.006705	6.544400	0.000919	5.960500	0.002208	1.772100	0.003609	4.844300	0.006433	5.122700	0.005012	5.318400	0.006465
4	2.066000	0.000639	2.721600	0.006240	5.558800	0.000909	4.982400	0.002174	1.109100	0.002883	3.892000	0.006224	4.162100	0.004876	4.352800	0.006311
5	1.378600	0.000529	1.938600	0.005476	4.598100	0.000886	4.039000	0.002096	0.635200	0.002060	3.002100	0.005816	3.255800	0.004601	3.436300	0.005990
6	0.856700	0.000401	1.298900	0.004473	3.684700	0.000843	3.157600	0.001959	0.332600	0.001316	2.209900	0.005178	2.437400	0.004154	2.601100	0.005459
7	0.494900	0.000278	0.815900	0.003378	2.846700	0.000773	2.368800	0.001753	0.159600	0.000752	1.545200	0.004344	1.737900	0.003551	1.878700	0.004722
8	0.265800	0.000176	0.479800	0.002350	2.111300	0.000678	1.698200	0.001490	0.070400	0.000388	1.022900	0.003414	1.176000	0.002852	1.289900	0.003848
9	0.132900	0.000102	0.264100	0.001508	1.498200	0.000566	1.160100	0.001196	0.028600	0.000182	0.639900	0.002503	0.753600	0.002144	0.840000	0.002941
10	0.062000	0.000055	0.136200	0.000894	1.014900	0.000446	0.753800	0.000903	0.010800	0.000077	0.378100	0.001711	0.456900	0.001506	0.518100	0.002104
11	0.027000	0.000027	0.065900	0.000492	0.655400	0.000332	0.465400	0.000641	0.003800	0.000030	0.211000	0.001092	0.262000	0.000989	0.302600	0.001408
12	0.011000	0.000012	0.030000	0.000251	0.403100	0.000233	0.273000	0.000428	0.001200	0.000011	0.111300	0.000652	0.142200	0.000608	0.167400	0.000884
13	0.004200	0.000005	0.012900	0.000120	0.236200	0.000154	0.152200	0.000268	0.000400	0.000003	0.055600	0.000364	0.073100	0.000351	0.087800	0.000520
14	0.001500	0.000002	0.005200	0.000054	0.131900	0.000096	0.080700	0.000159	0.000100	0.000001	0.026300	0.000192	0.035700	0.000190	0.043700	0.000288
15	0.000500	0.000001	0.002000	0.000022	0.070200	0.000057	0.040700	0.000089	0.000000	0.000000	0.011800	0.000095	0.016500	0.000097	0.020700	0.000150
16	0.000200	0.000000	0.000700	0.000009	0.035700	0.000032	0.019600	0.000047	0.000000	0.000000	0.005000	0.000044	0.007300	0.000047	0.009300	0.000075
17	0.000100	0.000000	0.000300	0.000003	0.017300	0.000017	0.009000	0.000024	0.000000	0.000000	0.002100	0.000019	0.003100	0.000021	0.004000	0.000035
18	0.000000	0.000000	0.000100	0.000001	0.008100	0.000008	0.004000	0.000011	0.000000	0.000000	0.000800	0.000008	0.001200	0.000010	0.001600	0.000016
19	0.000000	0.000000	0.000000	0.000001	0.003600	0.000004	0.001700	0.000005	0.000000	0.000000	0.000300	0.000003	0.000500	0.000004	0.000600	0.000007
20	0.000000	0.000000	0.000000	0.000000	0.001500	0.000002	0.000700	0.000002	0.000000	0.000000	0.000100	0.000001	0.000200	0.000002	0.000200	0.000003

Cost US$ x(1000)

	c		c
DLR-1	1,300	**DLR-5**	230
DLR-2	143	**DLR-6**	153
DLR-3	1,084	**DLR-7**	197
DLR-4	450	**DLR-8**	153

$$\Delta = \frac{EBO(s) - EBO(s+1)}{c}$$

Marginal Decrease in EBO for American Helicopters

	Engine		Int. Gearbox		Main R. Head		Main Gearbox		Tail Gearbox		Aux. Servo		Tail R. Head		Primary Servo	
s	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ
0	4.887500		5.875000		7.847800		7.410800		4.072900		6.970100		7.474500		7.322500	
1	3.895000	0.000763	4.877800	0.006973	6.848200	0.000922	6.411400	0.002221	3.089900	0.004274	5.971000	0.006530	6.475100	0.005073	6.323200	0.006531
2	2.939400	0.000735	3.897100	0.006858	5.851600	0.000919	5.416500	0.002211	2.176300	0.003972	4.978500	0.006487	5.479900	0.005052	5.328700	0.006500
3	2.073900	0.000666	2.964900	0.006519	4.867100	0.000908	4.438200	0.002174	1.403900	0.003358	4.008800	0.006338	4.500500	0.004972	4.351900	0.006384
4	1.355100	0.000553	2.127600	0.005855	3.914100	0.000879	3.500900	0.002083	0.823300	0.002524	3.092200	0.005991	3.560700	0.004771	3.418300	0.006102
5	0.815500	0.000415	1.429800	0.004880	3.022800	0.000822	2.639600	0.001914	0.437900	0.001676	2.267900	0.005388	2.694600	0.004396	2.563800	0.005585
6	0.451200	0.000280	0.895700	0.003735	2.228300	0.000733	1.890900	0.001664	0.211500	0.000984	1.572500	0.004545	1.938800	0.003837	1.825300	0.004827
7	0.229600	0.000170	0.522100	0.002613	1.560700	0.000616	1.281400	0.001354	0.093100	0.000515	1.026600	0.003568	1.320500	0.003139	1.228100	0.003903
8	0.107800	0.000094	0.283100	0.001671	1.035100	0.000485	0.819100	0.001027	0.037500	0.000242	0.629800	0.002593	0.848900	0.002394	0.778900	0.002936
9	0.046800	0.000047	0.143000	0.000980	0.648800	0.000356	0.493300	0.000724	0.013900	0.000103	0.362800	0.001745	0.514300	0.001698	0.465100	0.002051
10	0.018800	0.000022	0.067400	0.000529	0.384200	0.000244	0.279800	0.000474	0.004800	0.000040	0.196300	0.001088	0.293700	0.001120	0.261400	0.001331
11	0.007100	0.000009	0.029700	0.000264	0.214900	0.000156	0.149600	0.000289	0.001500	0.000014	0.099900	0.000630	0.158100	0.000688	0.138400	0.000804
12	0.002500	0.000004	0.012300	0.000122	0.113600	0.000093	0.075500	0.000165	0.000400	0.000005	0.047900	0.000340	0.080300	0.000395	0.069200	0.000452
13	0.000800	0.000001	0.004800	0.000052	0.056900	0.000052	0.036000	0.000088	0.000100	0.000001	0.021700	0.000171	0.038600	0.000212	0.032600	0.000239
14	0.000300	0.000000	0.001800	0.000021	0.027000	0.000028	0.016200	0.000044	0.000000	0.000000	0.009300	0.000081	0.017500	0.000107	0.014600	0.000118
15	0.000100	0.000000	0.000600	0.000008	0.012200	0.000014	0.007000	0.000020	0.000000	0.000000	0.003800	0.000036	0.007600	0.000050	0.006200	0.000055
16	0.000000	0.000000	0.000200	0.000003	0.005200	0.000006	0.002800	0.000009	0.000000	0.000000	0.001400	0.000016	0.003100	0.000023	0.002500	0.000024
17	0.000000	0.000000	0.000100	0.000001	0.002100	0.000003	0.001100	0.000004	0.000000	0.000000	0.000500	0.000006	0.001200	0.000010	0.001000	0.000010
18	0.000000	0.000000	0.000000	0.000001	0.000800	0.000001	0.000400	0.000002	0.000000	0.000000	0.000200	0.000002	0.000500	0.000004	0.000300	0.000005
19	0.000000	0.000000	0.000000	0.000000	0.000300	0.000000	0.000100	0.000001	0.000000	0.000000	0.000100	0.000001	0.000200	0.000002	0.000100	0.000001
20	0.000000	0.000000	0.000000	0.000000	0.000100	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000100	0.000001	0.000000	0.000001

Cost US$ x(1000) Δ

	c		c
DLR-1	1,300	**DLR-5**	230
DLR-2	143	**DLR-6**	153
DLR-3	1,084	**DLR-7**	197
DLR-4	450	**DLR-8**	153

$$\Delta = \frac{EBO(s) - EBO(s+1)}{c}$$

Marginal Decrease in EBO for English Helicopters

	Engine		Int. Gearbox		Main R. Head		Main Gearbox		Tail Gearbox		Aux. Servo		Tail R. Head		Primary Servo	
s	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ	EBO	Δ
0	6.499000		7.067500		10.770800		10.028100		4.856000		8.424700		8.551000		8.999200	
1	5.500500	0.000768	6.068400	0.006987	9.770800	0.000923	9.028100	0.002222	3.863800	0.004314	7.424900	0.006535	7.551200	0.005075	7.999300	0.006535
2	4.511800	0.000761	5.075200	0.006945	8.771100	0.000922	8.028600	0.002221	2.909400	0.004150	6.427000	0.006522	6.553000	0.005067	7.000600	0.006527
3	3.554900	0.000736	4.103400	0.006796	7.772500	0.000921	7.031300	0.002216	2.046700	0.003751	5.436800	0.006472	5.562000	0.005030	6.006800	0.006495
4	2.666800	0.000683	3.181700	0.006445	6.778400	0.000917	6.041500	0.002200	1.332500	0.003105	4.468600	0.006328	4.591000	0.004929	5.028000	0.006397
5	1.890600	0.000597	2.348600	0.005826	5.796000	0.000906	5.070200	0.002158	0.798600	0.002321	3.546300	0.006028	3.663200	0.004710	4.083000	0.006176
6	1.259700	0.000485	1.640800	0.004950	4.839000	0.000883	4.136200	0.002076	0.439800	0.001560	2.701700	0.005520	2.809000	0.004336	3.198800	0.005779
7	0.786400	0.000364	1.080500	0.003918	3.927500	0.000841	3.264600	0.001937	0.222700	0.000944	1.966000	0.004808	2.059700	0.003804	2.405600	0.005184
8	0.459300	0.000252	0.669200	0.002876	3.086100	0.000776	2.482300	0.001738	0.104000	0.000516	1.361400	0.003952	1.438800	0.003152	1.729600	0.004418
9	0.251000	0.000160	0.389400	0.001957	2.339100	0.000689	1.812000	0.001490	0.044900	0.000257	0.894900	0.003049	0.954900	0.002456	1.185400	0.003557
10	0.128500	0.000094	0.213000	0.001234	1.705000	0.000585	1.266400	0.001212	0.018000	0.000117	0.557600	0.002205	0.601200	0.001795	0.772900	0.002696
11	0.061700	0.000051	0.109600	0.000723	1.192500	0.000473	0.845900	0.000934	0.006700	0.000049	0.329200	0.001493	0.358900	0.001230	0.479000	0.001921
12	0.027900	0.000026	0.053200	0.000394	0.799100	0.000363	0.539500	0.000681	0.002300	0.000019	0.184200	0.000948	0.203200	0.000790	0.282000	0.001288
13	0.011900	0.000012	0.024300	0.000202	0.512600	0.000264	0.328400	0.000469	0.000800	0.000007	0.097800	0.000565	0.109200	0.000477	0.157900	0.000811
14	0.004800	0.000005	0.010500	0.000097	0.314700	0.000183	0.190800	0.000306	0.000200	0.000003	0.049300	0.000317	0.055700	0.000272	0.084100	0.000482
15	0.001800	0.000002	0.004300	0.000043	0.184900	0.000120	0.105800	0.000189	0.000100	0.000000	0.023600	0.000168	0.027000	0.000146	0.042600	0.000271
16	0.000700	0.000001	0.001700	0.000018	0.104000	0.000075	0.056100	0.000110	0.000000	0.000000	0.010800	0.000084	0.012500	0.000074	0.020600	0.000144
17	0.000200	0.000000	0.000600	0.000008	0.056000	0.000044	0.028500	0.000061	0.000000	0.000000	0.004700	0.000040	0.005500	0.000036	0.009500	0.000073
18	0.000100	0.000000	0.000200	0.000003	0.029000	0.000025	0.013800	0.000033	0.000000	0.000000	0.001900	0.000018	0.002300	0.000016	0.004200	0.000035
19	0.000000	0.000000	0.000100	0.000001	0.014400	0.000013	0.006400	0.000016	0.000000	0.000000	0.000800	0.000007	0.000900	0.000007	0.001800	0.000016
20	0.000000	0.000000	0.000000	0.000001	0.006800	0.000007	0.002900	0.000008	0.000000	0.000000	0.000300	0.000003	0.000400	0.000003	0.000700	0.000007

Cost
US$
x(1000) Δ

	c		c
DLR-1	1,300	DLR-5	230
DLR-2	143	DLR-6	153
DLR-3	1,084	DLR-7	197
DLR-4	450	DLR-8	153

$$\Delta = \frac{EBO(s) - EBO(s+1)}{c}$$

Marginal Decrease in EBO for French Helicopters

s	Engine EBO	Engine Δ	Int. Gearbox EBO	Int. Gearbox Δ	Main R. Head EBO	Main R. Head Δ	Main Gearbox EBO	Main Gearbox Δ
0	5.337200		6.221300		8.698300		8.190100	
1	4.342000	0.000766	5.223300	0.006979	7.698500	0.000922	7.190400	0.002222
2	3.372500	0.000746	4.237600	0.006893	6.700100	0.000921	6.192900	0.002217
3	2.471500	0.000693	3.290400	0.006624	5.708000	0.000915	5.204800	0.002196
4	1.692300	0.000599	2.422900	0.006066	4.734300	0.000898	4.242000	0.002140
5	1.075700	0.000474	1.679500	0.005199	3.800300	0.000862	3.331300	0.002024
6	0.632800	0.000341	1.090300	0.004120	2.935600	0.000798	2.505700	0.001835
7	0.344200	0.000222	0.661100	0.003001	2.171200	0.000705	1.796400	0.001576
8	0.173300	0.000131	0.374100	0.002007	1.531600	0.000590	1.223200	0.001274
9	0.080900	0.000071	0.197700	0.001234	1.027600	0.000465	0.789200	0.000964
10	0.035200	0.000035	0.097700	0.000699	0.654700	0.000344	0.482000	0.000683
11	0.014300	0.000016	0.045200	0.000367	0.395800	0.000239	0.278600	0.000452
12	0.005400	0.000007	0.019700	0.000178	0.227100	0.000156	0.152400	0.000280
13	0.001900	0.000003	0.008000	0.000082	0.123700	0.000095	0.079100	0.000163
14	0.000600	0.000001	0.003100	0.000034	0.064000	0.000055	0.038900	0.000089
15	0.000200	0.000000	0.001100	0.000014	0.031500	0.000030	0.018200	0.000046
16	0.000100	0.000000	0.000400	0.000005	0.014800	0.000015	0.008100	0.000022
17	0.000000	0.000000	0.000100	0.000002	0.006600	0.000008	0.003400	0.000010
18	0.000000	0.000000	0.000000	0.000001	0.002800	0.000004	0.001400	0.000004
19	0.000000	0.000000	0.000000	0.000000	0.001200	0.000001	0.000500	0.000002
20	0.000000	0.000000	0.000000	0.000000	0.000500	0.000001	0.000200	0.000001

s	Tail Gearbox EBO	Tail Gearbox Δ	Aux. Servo EBO	Aux. Servo Δ	Tail R. Head EBO	Tail R. Head Δ	Primary Servo EBO	Primary Servo Δ
0	4.322500		7.354100		7.824700		7.800000	
1	3.335800	0.004290	6.354700	0.006532	6.825100	0.005074	6.800400	0.006533
2	2.406400	0.004041	5.360100	0.006501	5.828600	0.005058	5.804000	0.006512
3	1.600900	0.003502	4.382700	0.006388	4.844400	0.004996	4.820100	0.006431
4	0.974000	0.002726	3.447800	0.006110	3.892100	0.004834	3.868600	0.006219
5	0.540100	0.001887	2.590900	0.005601	3.002200	0.004517	2.980200	0.005807
6	0.273100	0.001161	1.848700	0.004851	2.210000	0.004021	2.190500	0.005161
7	0.126200	0.000639	1.247100	0.003932	1.545300	0.003374	1.528900	0.004324
8	0.053500	0.000316	0.793200	0.002967	1.023000	0.002651	1.010100	0.003391
9	0.020900	0.000142	0.475100	0.002079	0.640000	0.001944	0.630500	0.002481
10	0.007500	0.000058	0.267900	0.001354	0.378100	0.001329	0.371600	0.001692
11	0.002500	0.000022	0.142400	0.000820	0.211000	0.000848	0.206900	0.001076
12	0.000800	0.000007	0.071400	0.000464	0.111300	0.000506	0.108800	0.000641
13	0.000200	0.000003	0.033800	0.000246	0.055600	0.000283	0.054200	0.000357
14	0.000100	0.000000	0.015200	0.000122	0.026300	0.000149	0.025600	0.000187
15	0.000000	0.000000	0.006400	0.000058	0.011800	0.000074	0.011500	0.000092
16	0.000000	0.000000	0.002600	0.000025	0.005000	0.000035	0.004900	0.000043
17	0.000000	0.000000	0.001000	0.000010	0.002100	0.000015	0.002000	0.000019
18	0.000000	0.000000	0.000400	0.000004	0.000800	0.000007	0.000800	0.000008
19	0.000000	0.000000	0.000100	0.000002	0.000300	0.000003	0.000300	0.000003
20	0.000000	0.000000	0.000000	0.000001	0.000100	0.000001	0.000100	0.000001

Cost US$ x(1000) $\bar{\Delta}$

	c		c
DLR-1	1,300	**DLR-5**	230
DLR-2	143	**DLR-6**	153
DLR-3	1,084	**DLR-7**	197
DLR-4	450	**DLR-8**	153

$$\Delta = \frac{EBO(s) - EBO(s+1)}{c}$$

APPENDIX F. TABLE OF SIMULATION RUNS FOR EACH ITEM ADDED TO INVENTORY LEVEL

Actual DLR name	Correlated name that appears in this appendix
Engine	DLR-1
Intermediate Gearbox	DLR-2
Main Rotor Head	DLR-3
Main Gearbox	DLR-4
Tail Gearbox	DLR-5
Auxiliary Servo	DLR-6
Tail Rotor Head	DLR-7
Primary Servo	DLR-8

		Inventory Level -- ITALY								
EBO	DLR	DLR-1	DLR-2	DLR-3	DLR-4	DLR-5	DLR-6	DLR-7	DLR-8	Achieved A_o
0.006983	DLR-2		1							0.1805
0.006918	DLR-2		2							0.1858
0.006705	DLR-2		3							0.1864
0.006535	DLR-8								1	0.1864
0.006533	DLR-6						1			0.1864
0.006521	DLR-8								2	0.1957
0.006513	DLR-6						2			0.2036
0.006465	DLR-8								3	0.2029
0.006433	DLR-6						3			0.2080
0.006311	DLR-8								4	0.2141
0.006240	DLR-2		4							0.2129
0.006224	DLR-6						4			0.2139
0.005990	DLR-8								5	0.2168
0.005816	DLR-6						5			0.2205
0.005476	DLR-2		5							0.2192
0.005459	DLR-8								6	0.2198
0.005178	DLR-6						6			0.2214
0.005075	DLR-7							1		0.2214
0.005062	DLR-7							2		0.2300
0.005012	DLR-7							3		0.2294
0.004876	DLR-7							4		0.2383
0.004722	DLR-8								7	0.2384
0.004601	DLR-7							5		0.2333
0.004473	DLR-2		6							0.2342
0.004344	DLR-6						7			0.2376
0.004301	DLR-5					1				0.2376
0.004154	DLR-7							6		0.2373
0.004089	DLR-5					2				0.2441
0.003848	DLR-8								8	0.2467
0.003609	DLR-5					3				0.2532
0.003551	DLR-7							7		0.2544
0.003414	DLR-6						8			0.2571
0.003378	DLR-2		7							0.2547
0.002941	DLR-8								9	0.2574
0.002883	DLR-5					4				0.2541
0.002852	DLR-7							8		0.2566
0.002503	DLR-6						9			0.2620
0.002350	DLR-2		8							0.2591
0.002222	DLR-4				1					0.2591
0.002219	DLR-4				2					0.2730
0.002208	DLR-4				3					0.2860
0.002174	DLR-4				4					0.2973
0.002144	DLR-7							9		0.2970
0.002104	DLR-8								10	0.2949
0.002096	DLR-4				5					0.2964

0.002060	DLR-5					5				0.3086
0.001959	DLR-4				6					0.3069
0.001753	DLR-4				7					0.3082
0.001711	DLR-6						10			0.3067
0.001508	DLR-2		9							0.3081
0.001506	DLR-7							10		0.3081
0.001490	DLR-4				8					0.3126
0.001408	DLR-8								11	0.3114
0.001316	DLR-5					6				0.3145
0.001196	DLR-4				9					0.3163
0.001092	DLR-6						11			0.3076
0.000989	DLR-7							11		0.3140
0.000922	DLR-3			1						0.3140
0.000922	DLR-3			2						0.3345
0.000919	DLR-3			3						0.3541
0.000909	DLR-3			4						0.3694
0.000903	DLR-4				10					0.3668
0.000894	DLR-2		10							0.3667
0.000886	DLR-3			5						0.3802
0.000884	DLR-8								12	0.3790
0.000843	DLR-3			6						0.3850
0.000773	DLR-3			7						0.3942
0.000767	DLR-1	1								0.3942
0.000753	DLR-1	2								0.4205
0.000752	DLR-5					7				0.4222
0.000714	DLR-1	3								0.4463
0.000678	DLR-3			8						0.4463
0.000652	DLR-6						12			0.4451
0.000641	DLR-4				11					0.4478
0.000639	DLR-1	4								0.4710
0.000608	DLR-7							12		0.4724
0.000566	DLR-3			9						0.4781
0.000529	DLR-1	5								0.4924
0.000520	DLR-8								13	0.4959
0.000492	DLR-2		11							0.4984
0.000446	DLR-3			10						0.5022
0.000428	DLR-4				12					0.4979
0.000401	DLR-1	6								0.5247
0.000388	DLR-5					8				0.5272
0.000364	DLR-6						13			0.5280
0.000351	DLR-7							13		0.5172
0.000332	DLR-3			11						0.5206
0.000288	DLR-8								14	0.5291
0.000278	DLR-1	7								0.5411
0.000268	DLR-4				13					0.5429
0.000251	DLR-2		12							0.5462
0.000233	DLR-3			12						0.5532
0.000192	DLR-6						14			0.5537
0.000190	DLR-7							14		0.5556
0.000176	DLR-1	8								0.5632
0.000182	DLR-5					9				0.5636
0.000159	DLR-4				14					0.5648
0.000154	DLR-3			13						0.5651
0.000150	DLR-8								15	0.5668
0.000120	DLR-2		13							0.5671
0.000102	DLR-1	9								0.5745
0.000096	DLR-3			14						0.5747
0.000097	DLR-7							15		0.5751
0.000089	DLR-4				15					0.5753
0.000095	DLR-6						15			0.5769
0.000077	DLR-5					10				0.5776
0.000075	DLR-8								16	0.5779
0.000057	DLR-3			15						0.5799
0.000055	DLR-1	10								0.5866
0.000054	DLR-2		14							0.5869

0.000047	DLR-4				16					0.5870
0.000047	DLR-7							16		0.5882
0.000044	DLR-6						16			0.5894
0.000035	DLR-8								17	0.5894
0.000032	DLR-3			16						0.5896
0.000030	DLR-5					11				0.5896
0.000027	DLR-1	11								0.5923
0.000024	DLR-4				17					0.5923
0.000022	DLR-2		15							0.5923
0.000021	DLR-7							17		0.5923
0.000019	DLR-6						17			0.5923
0.000017	DLR-3			17						0.5929
0.000016	DLR-8								18	0.5929
		DLR-1	**DLR-2**	**DLR-3**	**DLR-4**	**DLR-5**	**DLR-6**	**DLR-7**	**DLR-8**	**A_o**
Inventory Level		11	15	17	17	11	17	17	18	**59.00%**

		Inventory Level—USA								Achieved
EBO	DLR	DLR-1	DLR-2	DLR-3	DLR-4	DLR-5	DLR-6	DLR-7	DLR-8	A_o
0.006973	DLR-2		1							0.2006
0.006858	DLR-2		2							0.2068
0.006531	DLR-8								1	0.2070
0.006530	DLR-6						1			0.2072
0.006519	DLR-2		3							0.2075
0.006500	DLR-8								2	0.2172
0.006487	DLR-6						2			0.2217
0.006384	DLR-8								3	0.2300
0.006338	DLR-6						3			0.2324
0.006102	DLR-8								4	0.2351
0.005991	DLR-6						4			0.2370
0.005855	DLR-2		4							0.2400
0.005585	DLR-8								5	0.2405
0.005388	DLR-6						5			0.2422
0.005073	DLR-7							1		0.2429
0.005052	DLR-7							2		0.2493
0.004972	DLR-7							3		0.2507
0.004880	DLR-2		5							0.2563
0.004827	DLR-8								6	0.2572
0.004771	DLR-7							4		0.2607
0.004545	DLR-6						6			0.2615
0.004396	DLR-7							5		0.2617
0.004274	DLR-5					1				0.2646
0.003972	DLR-5					2				0.2726
0.003903	DLR-8								7	0.2741
0.003837	DLR-7							6		0.2754
0.003735	DLR-2		6							0.2757
0.003568	DLR-6						7			0.2760
0.003358	DLR-5					3				0.2829
0.003139	DLR-7							7		0.2834
0.002936	DLR-8								8	0.2836
0.002613	DLR-2		7							0.2835
0.002593	DLR-6						8			0.2867
0.002524	DLR-5					4				0.2873
0.002394	DLR-7							8		0.2927
0.002221	DLR-4				1					0.3012
0.002211	DLR-4				2					0.3066
0.002174	DLR-4				3					0.3160
0.002083	DLR-4				4					0.3232
0.002051	DLR-8								9	0.3255
0.001914	DLR-4				5					0.3277
0.001745	DLR-6						9			0.3306
0.001698	DLR-7							9		0.3308
0.001676	DLR-5					5				0.3344
0.001671	DLR-2		8							0.3349
0.001664	DLR-4				6					0.3351
0.001354	DLR-4				7					0.3387
0.001331	DLR-8								10	0.3389
0.001120	DLR-7							10		0.3364
0.001088	DLR-6						10			0.3396
0.001027	DLR-4				8					0.3400
0.000984	DLR-5					6				0.3411
0.000980	DLR-2		9							0.3469
0.000922	DLR-3			1						0.3613
0.000919	DLR-3			2						0.3642
0.000908	DLR-3			3						0.3842
0.000879	DLR-3			4						0.4001
0.000822	DLR-3			5						0.4013
0.000804	DLR-8								11	0.4106
0.000763	DLR-1	1								0.4260
0.000735	DLR-1	2								0.4305

0.000733	DLR-3			6						0.4367
0.000724	DLR-4				9					0.4370
0.000688	DLR-7							11		0.4413
0.000666	DLR-1	3								0.4641
0.000630	DLR-6						11			0.4644
0.000616	DLR-3			7						0.4713
0.000553	DLR-1	4								0.4870
0.000529	DLR-2		10							0.4960
0.000515	DLR-5					7				0.4987
0.000485	DLR-3			8						0.5012
0.000474	DLR-4				10					0.5026
0.000452	DLR-8								12	0.5034
0.000415	DLR-1	5								0.5238
0.000395	DLR-7							12		0.5245
0.000356	DLR-3			9						0.5280
0.000340	DLR-6						12			0.5245
0.000289	DLR-4				11					0.5313
0.000280	DLR-1	6								0.5458
0.000264	DLR-2		11							0.5423
0.000244	DLR-3			10						0.5501
0.000242	DLR-5					8				0.5509
0.000239	DLR-8								13	0.5556
0.000212	DLR-7							13		0.5562
0.000171	DLR-6						13			0.5573
0.000170	DLR-1	7								0.5617
0.000165	DLR-4				12					0.5648
0.000156	DLR-3			11						0.5655
0.000122	DLR-2		12							0.5668
0.000118	DLR-8								14	0.5671
0.000107	DLR-7							14		0.5645
0.000103	DLR-5					9				0.5705
0.000094	DLR-1	8								0.5810
0.000093	DLR-3			12						0.5834
0.000088	DLR-4				13					0.5809
0.000081	DLR-6						14			0.5818
0.000055	DLR-8								15	0.5802
0.000052	DLR-2		13							0.5822
0.000052	DLR-3			13						0.5827
0.000050	DLR-7							15		0.5807
0.000047	DLR-1	9								0.5879
0.000044	DLR-4				14					0.5878
0.000040	DLR-5					10				0.5916
0.000036	DLR-6						15			0.5916
		DLR-1	**DLR-2**	**DLR-3**	**DLR-4**	**DLR-5**	**DLR-6**	**DLR-7**	**DLR-8**	**A_o**
Inventory Level		9	13	13	14	10	15	15	15	**59.00%**

		Inventory Level—ENGLAND								Achieved
EBO	DLR	DLR-1	DLR-2	DLR-3	DLR-4	DLR-5	DLR-6	DLR-7	DLR-8	A_o
0.006987	DLR-2		1							0.1704
0.006945	DLR-2		2							0.1743
0.006796	DLR-2		3							0.1745
0.006535	DLR-8								1	0.1754
0.006535	DLR-6						1			0.1758
0.006527	DLR-8								2	0.1839
0.006522	DLR-6						2			0.1879
0.006495	DLR-8								3	0.1915
0.006472	DLR-6						3			0.1970
0.006445	DLR-2		4							0.1977
0.006397	DLR-8								4	0.1997
0.006328	DLR-6						4			0.2016
0.006176	DLR-8								5	0.2017
0.006028	DLR-6						5			0.2048
0.005826	DLR-2		5							0.2064
0.005779	DLR-8								6	0.2071
0.005520	DLR-6						6			0.2071
0.005184	DLR-8								7	0.2071
0.005075	DLR-7							1		0.2097
0.005067	DLR-7							2		0.2143
0.005030	DLR-7							3		0.2179
0.004950	DLR-2		6							0.2191
0.004929	DLR-7							4		0.2224
0.004808	DLR-6						7			0.2221
0.004710	DLR-7							5		0.2230
0.004418	DLR-8								8	0.2236
0.004336	DLR-7							6		0.2239
0.004314	DLR-5					1				0.2246
0.004150	DLR-5					2				0.2321
0.003952	DLR-6						8			0.2328
0.003918	DLR-2		7							0.2332
0.003804	DLR-7							7		0.2342
0.003751	DLR-5					3				0.2421
0.003557	DLR-8								9	0.2433
0.003152	DLR-7							8		0.2437
0.003105	DLR-5					4				0.2423
0.003049	DLR-6						9			0.2437
0.002876	DLR-2		8							0.2484
0.002696	DLR-8								10	0.2490
0.002456	DLR-7							9		0.2498
0.002321	DLR-5					5				0.2498
0.002222	DLR-4				1					0.2499
0.002221	DLR-4				2					0.2564
0.002216	DLR-4				3					0.2641
0.002205	DLR-6						10			0.2703
0.002200	DLR-4				4					0.2752
0.002158	DLR-4				5					0.2846
0.002076	DLR-4				6					0.2862
0.001957	DLR-2		9							0.2868
0.001937	DLR-4				7					0.2884
0.001921	DLR-8								11	0.2900
0.001795	DLR-7							10		0.2918
0.001738	DLR-4				8					0.2938
0.001560	DLR-5					6				0.2938
0.001493	DLR-6						11			0.2961
0.001490	DLR-4				9					0.2965
0.001288	DLR-8								12	0.2972
0.001234	DLR-2		10							0.2976
0.001230	DLR-7							11		0.2978
0.001212	DLR-4				10					0.2983
0.000948	DLR-6						12			0.2987
0.000944	DLR-5					7				0.2983

0.000934	DLR-4				11					0.2994
0.000923	DLR-3			1						0.3097
0.000922	DLR-3			2						0.3139
0.000921	DLR-3			3						0.3302
0.000917	DLR-3			4						0.3462
0.000906	DLR-3			5						0.3567
0.000883	DLR-3			6						0.3720
0.000841	DLR-3			7						0.3840
0.000811	DLR-8								13	0.3847
0.000790	DLR-7							12		0.3875
0.000776	DLR-3			8						0.3887
0.000768	DLR-1	1								0.3930
0.000761	DLR-1	2								0.4018
0.000736	DLR-1	3								0.4277
0.000723	DLR-2		11							0.4284
0.000689	DLR-3			9						0.4309
0.000683	DLR-1	4								0.4541
0.000681	DLR-4				12					0.4543
0.000597	DLR-1	5								0.4743
0.000585	DLR-3			10						0.4802
0.000565	DLR-6						13			0.4804
0.000516	DLR-5					8				0.4813
0.000485	DLR-1	6								0.5041
0.000482	DLR-8								14	0.5049
0.000477	DLR-7							13		0.5049
0.000473	DLR-3			11						0.5061
0.000469	DLR-4				13					0.5073
0.000394	DLR-2		12							0.5088
0.000364	DLR-1	7								0.5209
0.000363	DLR-3			12						0.5274
0.000317	DLR-6						14			0.5297
0.000306	DLR-4				14					0.5297
0.000272	DLR-7							14		0.5298
0.000271	DLR-8								15	0.5300
0.000264	DLR-3			13						0.5277
0.000257	DLR-5					9				0.5336
0.000252	DLR-1	8								0.5459
0.000202	DLR-2		13							0.5497
0.000189	DLR-4				15					0.5520
0.000183	DLR-3			14						0.5536
0.000168	DLR-6						15			0.5463
0.000160	DLR-1	9								0.5626
0.000146	DLR-7							15		0.5649
0.000144	DLR-8								16	0.5601
0.000120	DLR-3			15						0.5597
0.000117	DLR-5					10				0.5633
0.000110	DLR-4				16					0.5640
0.000097	DLR-2		14							0.5678
0.000094	DLR-1	10								0.5725
0.000084	DLR-6						16			0.5725
0.000075	DLR-3			16						0.5725
0.000074	DLR-7							16		0.5725
0.000073	DLR-8								17	0.5725
0.000061	DLR-4				17					0.5733
0.000051	DLR-1	11								0.5733
		DLR-1	**DLR-2**	**DLR-3**	**DLR-4**	**DLR-5**	**DLR-6**	**DLR-7**	**DLR-8**	**A_o**
Inventory Level		11	14	16	17	10	16	16	17	**57.00%**

		Inventory Level—FRANCE								Achieved
EBO	DLR	DLR-1	DLR-2	DLR-3	DLR-4	DLR-5	DLR-6	DLR-7	DLR-8	A_o
0.006979	DLR-2		1							0.1892
0.006893	DLR-2		2							0.1972
0.006624	DLR-2		3							0.1984
0.006533	DLR-8								1	0.1984
0.006532	DLR-6						1			0.1987
0.006512	DLR-8								2	0.2079
0.006501	DLR-6						2			0.2137
0.006431	DLR-8								3	0.2143
0.006388	DLR-6						3			0.2208
0.006219	DLR-8								4	0.2234
0.006110	DLR-6						4			0.2242
0.006066	DLR-2		4							0.2271
0.005807	DLR-8								5	0.2263
0.005601	DLR-6						5			0.2318
0.005199	DLR-2		5							0.2312
0.005161	DLR-8								6	0.2307
0.005074	DLR-7							1		0.2308
0.005058	DLR-7							2		0.2418
0.004996	DLR-7							3		0.2461
0.004851	DLR-6						6			0.2470
0.004834	DLR-7							4		0.2479
0.004517	DLR-7							5		0.2479
0.004324	DLR-8								7	0.2491
0.004290	DLR-5					1				0.2499
0.004120	DLR-2		6							0.2470
0.004041	DLR-5					2				0.2577
0.004021	DLR-7							6		0.2587
0.003932	DLR-6						7			0.2612
0.003502	DLR-5					3				0.2677
0.003391	DLR-8								8	0.2725
0.003374	DLR-7							7		0.2705
0.003001	DLR-2		7							0.2693
0.002967	DLR-6						8			0.2734
0.002726	DLR-5					4				0.2794
0.002651	DLR-7							8		0.2752
0.002481	DLR-8								9	0.2698
0.002222	DLR-4				1					0.2698
0.002217	DLR-4				2					0.2894
0.002196	DLR-4				3					0.3040
0.002140	DLR-4				4					0.3082
0.002079	DLR-6						9			0.3159
0.002024	DLR-4				5					0.3167
0.002007	DLR-2		8							0.3124
0.001944	DLR-7							9		0.3129
0.001887	DLR-5					5				0.3174
0.001835	DLR-4				6					0.3221
0.001692	DLR-8								10	0.3201
0.001576	DLR-4				7					0.3199
0.001354	DLR-6						10			0.3185
0.001329	DLR-7							10		0.3203
0.001274	DLR-4				8					0.3208
0.001234	DLR-2		9							0.3247
0.001161	DLR-5					6				0.3254
0.001076	DLR-8								11	0.3280
0.000964	DLR-4				9					0.3296
0.000922	DLR-3			1						0.3298
0.000921	DLR-3			2						0.3458
0.000915	DLR-3			3						0.3632
0.000898	DLR-3			4						0.3812
0.000862	DLR-3			5						0.3919
0.000848	DLR-7							11		0.3928

0.000820	DLR-6						11			0.3902
0.000798	DLR-3			6						0.4078
0.000766	DLR-1	1								0.4080
0.000746	DLR-1	2								0.4279
0.000705	DLR-3			7						0.4334
0.000699	DLR-2		10							0.4345
0.000693	DLR-1	3								0.4541
0.000683	DLR-4				10					0.4592
0.000641	DLR-8								12	0.4591
0.000639	DLR-5					7				0.4588
0.000599	DLR-1	4								0.4786
0.000590	DLR-3			8						0.4940
0.000506	DLR-7							12		0.4900
0.000474	DLR-1	5								0.5074
0.000465	DLR-3			9						0.5135
0.000464	DLR-6						12			0.5059
0.000452	DLR-4				11					0.5126
0.000367	DLR-2		11							0.5086
0.000357	DLR-8								13	0.5117
0.000344	DLR-3			10						0.5165
0.000341	DLR-1	6								0.5342
0.000316	DLR-5					8				0.5391
0.000283	DLR-7							13		0.5371
0.000280	DLR-4				12					0.5362
0.000246	DLR-6						13			0.5359
0.000239	DLR-3			11						0.5389
0.000222	DLR-1	7								0.5556
0.000187	DLR-8								14	0.5524
0.000178	DLR-2		12							0.5586
0.000163	DLR-4				13					0.5573
0.000156	DLR-3			12						0.5562
0.000149	DLR-7							14		0.5576
0.000142	DLR-5					9				0.5608
0.000131	DLR-1	8								0.5748
0.000122	DLR-6						14			0.5706
0.000095	DLR-3			13						0.5761
0.000092	DLR-8								15	0.5749
0.000089	DLR-4				14					0.5747
0.000082	DLR-2		13							0.5739
0.000074	DLR-7							15		0.5696
0.000071	DLR-1	9								0.5846
0.000058	DLR-5					10				0.5846
0.000058	DLR-6						14			0.5846
0.000055	DLR-3			14						0.5846
0.000046	DLR-4				15					0.5846
0.000043	DLR-8								16	0.5846
0.000035	DLR-1	10								0.5924
		DLR-1	**DLR-2**	**DLR-3**	**DLR-4**	**DLR-5**	**DLR-6**	**DLR-7**	**DLR-8**	**A_o**
Inventory Level		10	13	14	15	10	14	15	16	**59.00%**

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